

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

ENERGY & ENVIRONMENT DIVISION

OPTICAL INTERFERENCE COATINGS FOR IMPROVED LUMINAIRE PERFORMANCE: FINAL REPORT

Harry L. Rubins

January 1981

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OPTICAL INTERFERENCE COATINGS FOR IMPROVED LUMINAIRE PERFORMANCE

FINAL REPORT

Harry L. Rubins*

Lawrence Berkeley Laboratory University of California Berkeley, California 94720 January 1981

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OPTICAL INTERFERENCE COATINGS FOR IMPROVED LUMINAIRE PERFORMANCE

ABSTRACT

An interior broadbeam HID uplight and an upstream roadway luminaire were developed to demonstrate that optical coated luminaire components can improve the visual effectiveness and energy efficiency of a lighting system.

Optical coated reflectors and flat lens covers were very effective in the development of new improved lighting techniques. The coatings reduce reflection and transmission losses, opening the door to new design options for improving lighting performance and saving energy.

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OPTICAL INTERFERENCE COATINGS FOR IMPROVED LUMINAIRE PERFORMANCE

1.0 INTRODUCTION

In our efforts to conserve lighting energy, more must be done than developing and increasing the use of high efficacy lamps and more efficient ballasts. In many applications large energy savings can be achieved, simply by development of improved lighting techniques for specific visual tasks.

In this report the term <u>lighting technique</u> is defined as a method of distributing light to a visual task in order to produce a carefully defined visual effect. For the freeway interchange luminaire design, the performance is specified in terms of luminance levels and ratios... not simply footcandles.

In the development of new lighting techniques the following should be considered:

- The re-examination of basic visual needs (including the precise definition of the visual task).
- The specification of these needs in terms of luminance levels and ratios in the visual scene.
- The development of new and more efficient ways of distributing light for greater visual effectiveness.
- The use of improved (and often somewhat more costly) light control components and materials.

On an equal footcandle basis, routine calculations can establish the long range savings achieved by a change to relatively expensive, high efficacy lamps. But it is not so easy to put a dollar value on the benefit of a new

lighting technique that provides improved visibility (visually optimized luminance levels and ratios). Therefore, the electric lighting industry has often faced difficulties in marketing relatively expensive luminaires that provide improved lighting performance (unique visually effective light distribution characteristics, improved glare control, etc.).

It is understandable that luminaire manufacturers usually wait for the user to specify better lighting techniques, components and materials. But since the user ordinarily has little knowledge of lighting theory and technology, he, in turn, waits for the manufacturer to offer improved products. The user must also be persuaded that these products are indeed superior and have real benefits (although the visual benefits may resist cost-value analysis).

In order to alleviate this problem, Lawrence Berkeley Laboratory (LBL), Berkeley, California assists the U. S. Department of Energy (DOE) in planning and encouraging the development of improved lighting components, materials control systems and techniques.

One of the LBL projects is to identify opportunities for improved luminaire design and performance. The project supports the development and demonstration of luminaires providing improved visual performance and energy efficiency.

Optical Coating Laboratory, Inc. (OCLI) in Santa Rosa, California had recently introduced to the lighting industry optical interference coatings to enhance the reflectivity of prefinished anodized aluminum lighting sheet and to increase high angle transmission for flat tempered glass luminaire covers. The LBL project to support improved luminaire design and performance was an effective means of demonstrating the new design media from OCLI.

Two energy efficient luminaire designs were selected for design prototyping and photometric testing:

- Wide beam HID interior uplight
- Roadway interchange luminaire

The original objective for the interchange luminaire was to establish the performance and energy benefit of optical coated enhanced specular reflectors in conventional roadway luminaires. With the encouragement of Mr. Rudy Verderber of LBL, the original objective was expanded to this first stage development of a new lighting technique (upstream freeway luminaires) for critical areas on freeways ("partial interchange lighting").

LBL administered the DOE contract on a cost sharing basis with OCLI. The liminaire design and prototyping was subcontracted by OCLI to John Brass, Lighting Research and Development Inc., San Rafael, California. John also contributed significantly to the writing of this report.

2.0 WHAT ARE OPTICAL INTERFERENCE COATINGS?

Optical interference coatings are relatively new to the lighting industry, although they have been used for many years in cameras, projectors, and other optical instruments. Optical coatings can reduce reflection from camera lens surfaces, increase reflectance of mirrors, separate heat from light in slide and movie projectors, filter light according to color, or perform other light control functions. Naturally occurring examples of optical interference are soap bubbles and oil slicks. Also, many birds, insects, and fish get their irridescent colors from interference films.

The application of these coatings can significantly increase the reflectance of aluminum lighting sheet or increase the transmission of light at high angles through luminaire covers.

Interference coatings are made by depositing vaporized materials onto the substrate in a vacuum chamber.

The materials used include metals such as silver and aluminum; semi-conductors such as silicon and germanium; and inorganic dielectrics such as magnesium fluoride and titanium dioxide. Coatings can be applied to a variety of substrates, such as glass, aluminum and plastic. These coatings have been referred to as thin films because the thickness of a single layer is about 0.1 micron (about 4 millionths of an inch). The coatings of interest for the lighting industry are multilayered with a total thickness less than 1 micron.

Vacuum coating technology has only been available since the mid-1930's. The coatings were applied in small batch-type bell jars and were not previously economic. Current technology has developed larger, more cost effective processes that make them more of an interest to the lighting industry.

3.0 LIGHT CONTROL MATERIALS

The optical coatings, which are of interest to the lighting industry, are enhanced reflector coatings on lighting sheet and antireflection coatings on flat glass light covers to improve the transmission of light at high angles (grazing).

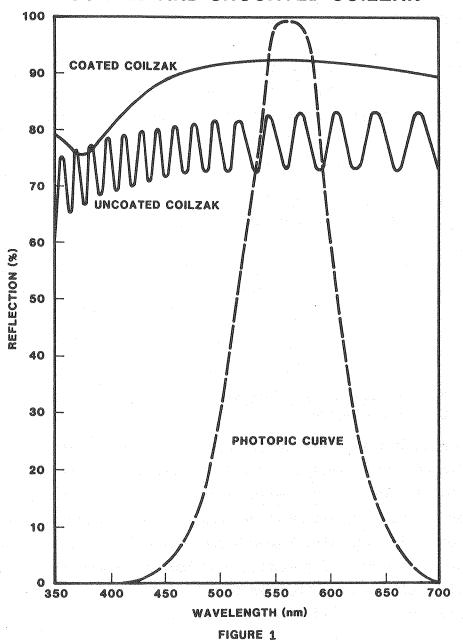
3.1 Enhanced Reflectors

When multilayer optical coatings are applied to specular lighting sheet, the reflectance is enhanced. For Coilzak specular lighting sheet, the total reflectance (specular and diffuse), as measured by the Diano TR-1 Reflectometer, is increased from 83% to 94%. This represents an increase of about 13% in light output for a single reflection from the coated reflector.

A spectral scan (Figure 1) from a Cary 14 Spectrophotometer shows the spectral reflectance, in the visible region, for optical coated and uncoated Coilzak anodized lighting sheet. The photopic eye response is overlaid as a dotted line to show that the coating performance is maximized in the region where the eye is most sensitive.

The spectral oscillations in the uncoated scan are characteristic of anodized aluminum. They result from optical interference affects in the anodized layer on the surface of the aluminum. The difference between the values for total and specular reflectance in Table 1 is the diffuse component of reflectance. The coating improved specularity by reducing the diffuse reflectance of the uncoated lighting sheet from 5% to 2%. For a design which requires a high degree of light control, the coated reflector will be useful because light scatter and glare are reduced.

TYPICAL SPECTRAL SCAN COATED AND UNCOATED COILZAK



The use of multiple reflections in luminaire design is generally not advocated by some designers because of high reflection losses. For example, with ordinary specular aluminum reflectors having a specular reflectance of approximately 78% (83% total reflectance), the luminous intensity of a light ray after the fourth reflection is reduced to 37% of the initial value of the lamp (Table 1). However, the rigorous adherence to the single reflection rule often makes it impossible to direct light to the visual task zone in a precise way.

These light losses, due to multiple reflections, have been greatly reduced in the prototype luminaire by the application of optical interference coatings to enhance the reflection of standard lighting sheet.

Table 1

Reflectance of Coilzak® Specular Lighting Sheet
With and Without Optical Coatings

				Multi	pie Ketieci	cions
		Initial			(Specular)	
	To	tal*	Specular**	2nd		4th
Coated	9	4%	92%	85%		72%
Uncoated	8	3%	7 8%	61%		37%

*Diano TR-1 Reflectometer (Photopic response)
**Cary 14 Spectrophotometer

The improvement in both total and specular reflectance is shown in Table 1. Total reflectance is increased by 11% (abs.) and specular reflectance is increased by 14% (abs.). This improvement results in performance and energy benefits even for luminaire designs that rely on single reflections. The most impressive benefits, however, are obtained when designs make use of multiple reflections. For example, the luminous intensity of a light ray (specular reflectance) after the fourth reflectance is nearly doubled when enhanced optical coated reflectors are used (72% vs. 37%).

[®] Alcoa Trademark.

3.2 Enhanced Transmission Materials

A different multilayer optical coating design is applied to glass or a flat luminare cover to enhance transmittance. The coating is called an antireflection coating because it reduces the reflectance losses at the two surfaces of the glass.

Glass transmits about 91% of the light when the light is at normal incidence, i.e., perpendicular to the glass surface. The transmittance of light is dependent on the angle of incidence of the light. As the angle of incidence increases, i.e., becomes more grazing, the transmittance decreases due to increased reflectance losses. Between 0 and 30°, the transmission changes very little. For angles greater than 30°, the loss in transmission gets much greater. For an uncoated lens, the transmittance at 65° incidence angle is now only 77%. For a sharp cut-off luminaire, the maximum candle power beam is between 60° and 70° incidence angle. When an antireflection coating that is optimized for high angles, is applied to both surfaces, the transmittance at 65° is increased to 89%. This allows more light to be transmitted at high angles where it is needed to provide a more uniform light pattern.

In Figure 2, a spectral scan of an optical coated and uncoated lens shows the transmittance across the visible region. The photopic eye response is overlaid in dotted lines to show that the coating performance is maximized in the region where the eye is most sensitive.

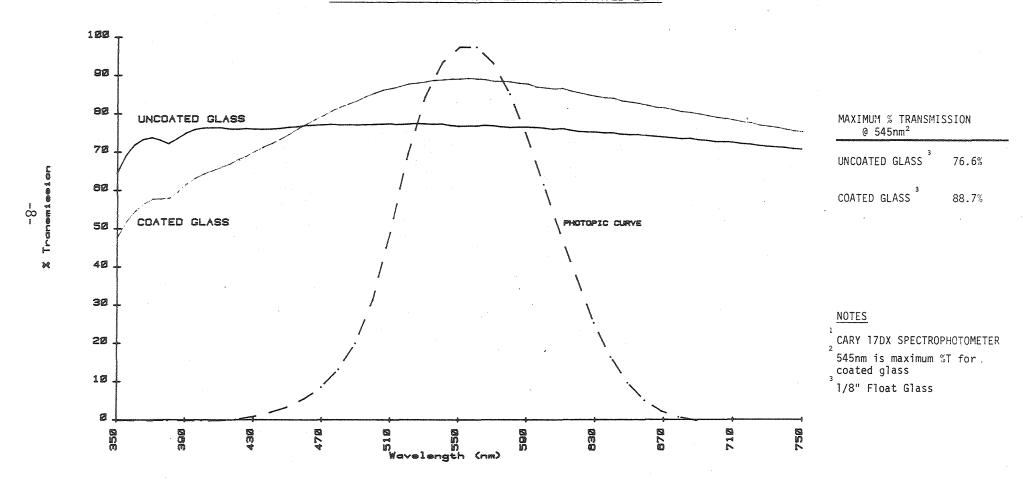
3.3 Reflector Fabrication

The reflector systems in both prototype luminaire designs were fabricated from flat prefinished aluminum lighting sheet. Reflectors made from this sheet have a degree of specularity (specular reflectance) that cannot be achieved in reflectors that are finished after fabrication (i.e., hydroformed or spun). Currently, it is more economical to apply optical coatings to flat lighting sheet than to formed reflectors.

FIGURE 2

% TRANSMISSION MEASURED 1 AT 65 DEGREES

OCLI'S TYPE IIAR COATED LENS VS. UNCOATED LENS



Two sets of lighting sheet reflectors for each prototype design were made for comparative photometric tests; one using specular lighting sheet (smooth or hammertone) and the second set using the same with optical coatings. The reflector systems were designed so they could be reproducibly fabricated in a typical manufacturing facility. The same fabrication techniques were used to make both sets of reflectors for each design. There were no special handling requirements for the coated lighting sheet during fabrication.

Under normal handling in fabrication and end use conditions, coated lighting sheet is durable and will retain its high reflectivity. The coating does not flake or peel as it has excellent adhesion to the substrate. Since the coating is inorganic, it does not char, burn, or give off fumes at high temperatures.

3.4 Cleaning and Durability of Coated Components

Dirt or grease on the coated reflectors and lenses can be easily cleaned off. The maintenance of coated components is basically no different than for uncoated components. This is because the coating is impervious to dust and dirt. A clean soft cloth is sufficient to remove loose particles. As with uncoated anodized lighting sheet, scouring pads, abrasive cleaners, and acids are not recommended. For removing heavier soils, the same type cloth is used with water, detergents, ammonia-based window cleaners and certain solvents [acetone, benzene, xylene and methylethylketone (MEK)].

The durability of coated reflectors in fully enclosed outdoor luminaires has been excellent. This has been shown in accelerated aging tests conducted by luminaire manufacturers and in luminaire service tests conducted by OCLI at various locations around the country over 3-1/2 years service to date.

4.0 WIDE BEAM HID INTERIOR UPLIGHT

The interior uplight was one of two luminaire designs that were created during this project. It was developed to demonstrate the effectiveness of optical coatings on reflectors and glass covers to significantly improve the efficiency and beam width of an uplight luminaire. This broad beam unit with coated components was specifically designed to provide a relatively large rectangular uniform light pattern on the ceiling from a mounting distance of only two to four feet (down from the ceiling). An example of how this wide beam uplight can be installed in an open office is shown in Figure 3. In this illustration, the luminaire is pole mounted on top of office partitions. It could also be installed using a free standing kiosk.

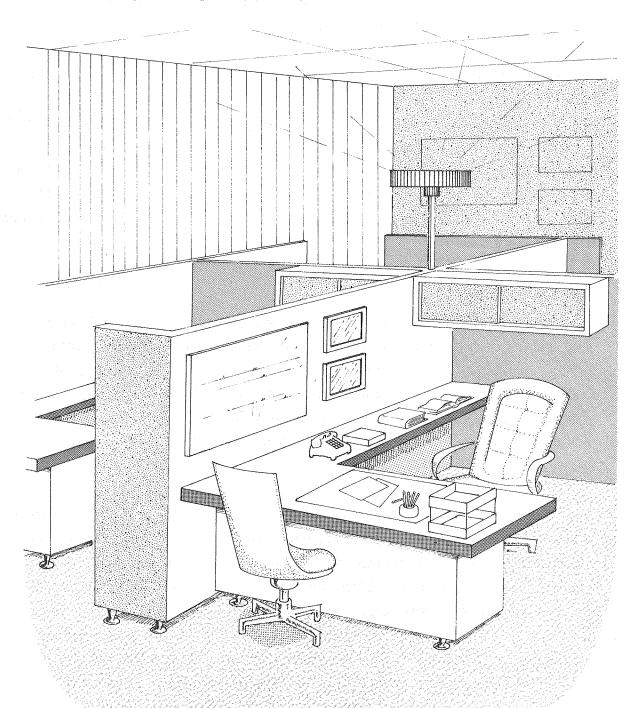
Other design objectives required in a broad beam uplight are:

- 1. Straight up candlepower should be limited to the maximum (broadside) candlepower of a bare lamp (about 2700 cd. for a 25,000 lumen "white" HPS lamp). Presently, a typical (undesirable) figure for "state of the art" broad beam HID uplights is about 1.65 to 1.85 times the bare lamp maximum candlepower. This has three disadvantages: (a) excessive ceiling brightness (glare) directly above the unit, (b) reduced light availability for the perimeter of the beam, and (c) the ceiling hot spot does not redistribute light to the work area as efficiently as a broader pattern.
- 2. The illumination towards the perimeter of the pattern should be at a relatively flat angle using a protective top cover glass.*

 A desirable angle for maximum candlepower(in a broad beam unit) is 20 to 30 degrees above the horizontal (vertical photometric angle of 120 degrees). This can provide excellent ceiling brightness uniformity for a luminaire spacing of 16 feet with 4 foot mounting distances from the ceiling and satisfactory uniformity up to 24 feet spacing.

*NOTE: A tempered top cover glass is essential for the safe operation amd maintenance of a HID uplight. Care should be taken in reading photometric data to see if a cover glass was used.

TYPICAL INSTALLATION OF WIDE BEAM UPLIGHT



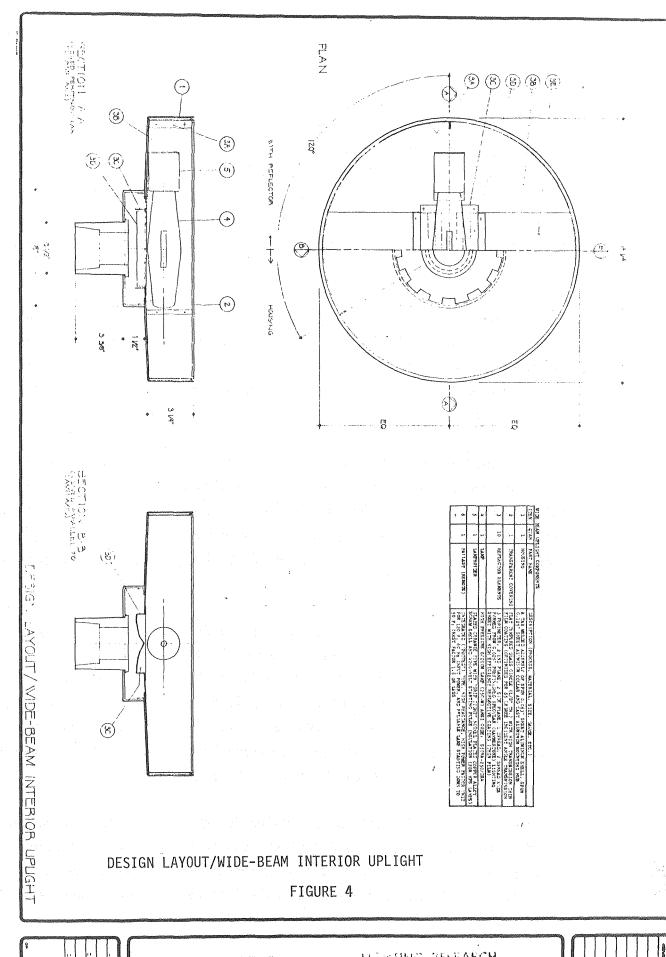
3. The lighted ceiling should be free of hot spots, striations and other visually obvious irregularities. This is difficult to achieve with a clear bulb HID lamp (particularly with HPS lamps which have a pencil thin arc tube). One method used to obtain a uniform light pattern is to use a stippled glass cover when clear bulb lamps are used. However, the stippled lens reduces the maximum beam candlepower.

Transmission losses at high incidence angles were reduced by coating the top glass cover with an OCLI antireflection coating on both sides. Uniform light distribution was obtained by using optical coated prefinished specular hammertone reflector material. The random embossed pattern smooths the light distribution without introducing reflection losses. Multiple reflections at the perimeter ring reflector also help to obtain uniform light distribution. This type of pattern smoothing design benefits significantly from the addition of thin film reflector coatings.

4.1 Physical Description

The prototype uplight design (Figure 4) has a shallow housing, 3 inches deep and 18 inches in diameter. With various mounting supports, this shallow housing can be an attractive addition to an office arrangement (standard or open). A slender, supporting pole will present much less of a visual interference in an open space than conventional uplights. The ballast would be of the sound isolated type mounted in the base or a remote box.

The tempered top glass cover is a "lay-in" circle which rests on perimeter reflector tabs. The three section perimeter reflector fits snuggly into the housing sides. The bottom side plane reflectors direct grazing angle light toward the perimeter reflector. Flat specular reflectors might be substituted for the hammertone bottom side plane reflectors to obtain additional improvement in performance. Excessive straight up candlepower is prevented by the central uplight spread reflector (under the lamp) which is faceted to spread light rather than reinforce the upward component. It is also designed to prevent focusing of light back on the lamp arc tube.



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4.2 Lighting Performance

The coated prototype provided unusually uniform broad beam performance (photometric test reports from Lighting Sciences are in the appendix). The efficiency (total light output/bare lamp output) was very high, 75.4% for the coated prototype and 63.5% for the uncoated prototype. Even for the uncoated prototype, this represents good performance for a unit without excessive straight up candlepower and 120 degree main beams (30 degrees above the horizontal).

Some contemporary uncoated uplights with top covers develop equally high or somewhat higher efficiency because they allow excessive straight up candlepower. When most light is allowed to go straight up, the total efficiency tends to be high at the expense of distribution efficiency (uniformity).

With a 25,000 lumen "white" HPS lamp (250 watt), the straight up candle-power was appropriately low (approximately 2700 candelas) in both coated and uncoated versions. However, the main beam had a candlepower of 8304 candelas in the coated version and only 6576 candelas in the uncoated version! This represents an increase of 26% in perimeter candlepower and ceiling illumination.

Because of simplistic assumptions made in coefficient of utilizations (CU) computation programs (assumption of perfectly diffusing ceilings, etc.), the large room CU figure of 0.63 vs. 0.53 for the uncoated version (19% improvement) does not show the full benefit of improved ceiling brightness uniformity. However, even the 19% improvement represents a lighting efficiency improvement of far greater magnitude than obtained by other energy management techniques (better ballasts, etc.).

The development of the uplight luminaire design with optical coated components provides efficient and uniform light distribution for greater visual effectiveness. The non-glare diffuse lighting will produce unusually good visibility in offices and business installations for general and task lighting.

This new luminaire design will be particularly useful for video display terminal (CRT) installations in offices or computer rooms. The CRT terminal presents some unusual lighting problems. The lighted display screen is a vertical task which is best viewed under low levels of illumination. The higher levels of illumination needed for horizontal office tasks are not good for long term use with the vertical CRT screen. This is particularly true in most offices where ceiling down lights are used. The bright luminaire images are reflected on the screen reducing readability and increasing operator fatigue. This situation can be improved by using uplights (indirect) with uniform diffuse light distribution in combination with antireflection surfaces on the CRT screen. The glare from the ceiling and other images will be greatly reduced.

The OCLI coated wide beam uplight had a total efficiency of 79.7% without a cover glass. However, the maximum candlepower without a cover was not greater than with cover glass! This is an unusual result depending partly on the "wave guide" principle of the closely spaced lower reflector planes and the top cover. In other words, with most uplight designs, the coated cover alone would not normally raise the maximum beam candlepower to the level without cover.

4.3 <u>Cost Benefit Using Coated Luminaire Components</u>

The OEM manufactured selling price for this new luminaire design with coatings is \$275.00 and without coatings is \$241.00 (Table 2, Item I). The final installed costs increase to \$627.00 and \$576.00, respectively, by the time the lamp support base and installation are added (Table 2, Item II). The various markups for manufacturing and installation increase the costs for a coated reflector and lens cover from \$20.00 at the manufacturing level to \$51.00 after installation. This represents 8.2% of the installed costs.

The increased cost for the luminaire with optical coated components is more than offset by the cost savings using fewer luminaires with improved performance (Table 3). This includes both a savings in installed cost and in annual utility costs.

TABLE 2

MANUFACTURING AND INSTALLED COST CALCULATIONS: HID UPLIGHT LUMINAIRE

			OEM COSTS		TOTAL	COSTS
			MATERIAL	LABOR	COATED	UNCOATED
Ι.	<u>LUM</u>	INAIRE MANUFACTURING COSTS				
	Α.	Housing				
•		A tab-welded assembly of spun 0.063" sheet aluminum shell, spun 0.125" sheet aluminum collar and cast aluminum mounting hub.		•		
		 Shell 0.898# x 4.72 ft.² x 120% x \$1.12/lb. 	\$ 5.69	\$ 8.00	\$13.69	
		 Collar 1.78# x 1.00 ft.² x 120% x \$1.12/1b. 	2.39	5.00	7.39	
		• Hub 2#	4.00	2.00	6.00	
		• Assembly		7.00	7.00	
		SUBTOTAL:			\$34.08	\$34.08
	В.	Reflector Elements				
		10 elements formed from 0.025" prefinished specular (hammertone grain) lighting sheet with OCLI enhanced high reflector thin film coating.				
		 Hammertone substrate (not Kinglux) 4.25 ft.² (including drop) \$1.20/ft.² (5000 lb. price) 130% pass through markup 	\$ 6.63	\$15.00	\$21.63	\$21.63
		• OCLI Coating (one side)				
		\$1.55/ft. ² (10,000 ft. ² price)	6.59	***	6.59	us == 000
		SUBTOTAL:			\$28.22	\$21.63
					(Co	ontinued)

TABLE 2 (Cont.)

MANUFACTURING AND INSTALLED COST CALCULATIONS: HID UPLIGHT LUMINAIRE

		<u>OEM</u>	COSTS	TOTAL	COSTS
		MATERIAL	LABOR	COATED	UNCOATED
I.	LUMINAIRE MFG. COSTS (Cont.)				
	C. Transparent Cover				
	Flat tempered glass circle (1/8" thick x 18.25" dia.) with OCLI antireflection thin film coating (optimized for 65° incident angle transmission).				
	Tempered Glass Circles	\$ 2.85	ain tip mi mp	\$ 2.85	\$ 2.85
	OCLI Coating (both sides)	13.69	100 min 100 min	13.69	500 600 ees 600
	SUBTOTAL:			\$16.54	\$ 2.85
	D. <u>Assembly</u>				
	• Lampholder	1.75	.50	2.25	
	Ballast Assembly (special quiet design)			60.00	
	Standard Fasteners, etc.	1.00		1.00	
	• Final Assembly	10.00		10.00	
	Painting	5.00		5.00	·
	Packaging	5.00		5.00	
	SUBTOTAL:			\$83.25	\$83.25
	TOTAL MANUFACTURING COST :			\$162.09	\$141.81
	E. <u>OEM Selling Price</u>				**************************************
	(170% Markup for moderate quantity)			\$276.00	\$241.00

(Continued)

TABLE 2 (Cont.)

MANUFACTURING AND INSTALLED COST CALCULATIONS: HID UPLIGHT LUMINAIRE

					TOTAL	COSTS
		14 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			COATED	UNCOATED
II.	INSTALLE	ED COST		*		
	A. Comp	ponents				•
		_uminaire			\$276.00	\$241.00
	• 2	250-watt HPS Lamp			40.00	40.00
	8 1	Kiosk Base			80.00	80.00
			SUBTOTAL:		\$396.00	\$361.00
	B. Ins	tallation				
	® (Contractor's Markup (40)%)		\$158.75	\$144.50
			SUBTOTAL:		\$554.75	\$505.50
	8	Sales Tax (6%)			33.25	30.50
		$\mathcal{L}_{i} = \mathcal{H}_{i} = \mathcal{H}_{i}$	SUBTOTAL:		\$587.00	\$536.00
	•	Labor (1 hour includes	all fringes, profit, etc.)		40.00	40.00
			TOTAL INSTALLED COST:		\$627.00	\$ <u>576.00</u>
			PRICE DIFFERENCE AS INSTALLE	D:	\$ <u>5</u> -	1.00

TABLE 3

ECONOMIC STUDY - HID UPLIGHT LUMINAIRE

OPEN OFFICE LUMINAIRE LAYOUT I.

A. Office Dimensions

Ceilings: 10 ft. height

80% reflectance *

Walls:

50% reflectance

B. Luminaire Spacing

Spacing: 8 ft. x 16 ft. centers

Floor Mounting:

6 ft. high (4 ft. below ceiling)

Room Cavity Ratio: $\frac{5h (L+W)}{} = 0.53 \text{ (use RCR = 1)}$

LxW

Calculations

1. Coefficient of Utilization

Coated Luminaire

0.63 (LSI Test Report 1069)

Uncoated Luminaire

0.53 (LSI Test Report 1072)

2. Illumination (F X CU x MF)

F = 25,000 lumens, MF = .80, A = 8x16

Coated Luminaire

98 fc

Uncoated Luminaire

82 fc (needs 20% more luminaires)

(Continued)

TABLE 3 (Cont.)

ECONOMIC STUDY - HID UPLIGHT LUMINAIRE

I. OPEN OFFICE LUMINAIRE (Cont.)

C. Calculations (Cont.)

3. Number of Luminiares for 100 fc (goal)

Coated Luminaire

20 units

Uncoated Luminaire 24 units (20% more)

II. OPEN OFFICE INSTALLED COSTS

COSTS

	COATED	UNCOATED
Cost per unit (Table 2)	\$ 627.00	\$ 576.00
System cost for the office	\$12,540.00 (20 units)	\$13,824.00 (24 units)

COST SAVINGS USING COATED LUMINAIRES:

1,284.00

III. ANNUAL ELECTRICAL COST SAVINGS

ANNUAL ELECTRICAL COSTS

@ 4.000 HRS/YR

	Lamp			e 4,000	11/3/1/
	Rated	20% Ballast Loss	<u>Units</u>	@ 4 cents/KWH	@ 12 cents/KWH
Coated Luminaire	250-Watt	300-Watt	20	\$ 960.00	\$2,880.00
Uncoated Luminaire	250-Watt	300-Watt	24	\$1,152.00	\$3,456.00
ANNUAL COST SAVINGS	USING COATE	D LUMINAIRES:		\$ <u>192.00</u>	\$ <u>576.00</u>

The economic analysis was developed using a 40 x 96 foot open office with 10 foot ceiling. The rectangular light pattern from the prototype luminaire gives excellent uniformity with 8 x 16 foot spacing. The calculated illumination of 98 fc for the coated luminaire met the goal of 100 fc for the open office. The uncoated luminaire had calculated illumination of 82 fc. Therefore, only 20 units of the optical coated luminaire are needed for this open office, whereas, 24 units are needed for the uncoated luminaire.

A 10% cost savings of \$1,284.00 is realized because four less luminaires are required even though the unit cost of the coated luminaire is slightly higher. In addition to the first cost savings, annual utility charges will be lower for each year during the life of the system. With fewer units, the annual savings are \$192.00 at 4 cents/KWH and are \$576.00 when the utility rate is 12 cents/ KWH.

4.4 Conclusions

Enhanced reflectance and transmittance luminaire components using optical interference coatings have significantly improved the performance of HID broadbeam uplight luminaires.

The use of optical coatings made it possible to overcome some of the deficiencies of existing HID uplights by reducing straight up candle power and increasing the maximum beam candle power. This reduced glare, improved uniformity and perimeter candle power. The high efficiency luminaire was achieved with relatively simple optical designs that are easily fabricated. Therefore, this new design, using optical coatings, could be produced using existing production methods for use now to give better office lighting at a lower cost.

As a result of the improved luminaire efficiency, 20% fewer luminaires were required for a typical open office installation providing a given illumination level. This resulted in a 20% reduction in energy consumption and annual energy cost. In addition, there was a savings in the capital cost of the lighting

system. Since fewer luninaires were needed, a 10% savings in the installed cost was realized. The small added cost for optical coated components in each luminaire was more than off-set by the savings in purchasing four less luminaires.

5.0 UPSTREAM ROADWAY INTERCHANGE LIGHTING

The roadway interchange luminaire was the second of the two designs that were created during this project. The original objective was to establish the performance and energy benefit of optical coated reflectors in conventional sharp cutoff roadway luminaires but was later expanded to include the development of new lighting techniques:

- Upstream luminaire
- Task lighting of critical areas at interchanges

5.1 "Upstream" Design Concept

Ancient street lanterns provided reasonably good visibility of pedestrians and carriages because of the silhouette effect (back lighted). Even the feeble amount of light from oil lanterns produced sufficient pavement brightness to provide a visually effective silhouette background for dark adapted eyes. Paintings, photographs and movies showing old fashioned night time street scenes often dramatize this silhouette effect. Therefore, long before electric street lights came into existence, it was known that night time traffic is perceived principally by the silhouette effect.

5.1.2 Twin-Beam Luminaires

In the early days, street lights were little more than a light source in a weatherproof enclosure. In the late 1920's asymmetric, twin-beam lights using incandescent lamps were introduced. These luminaires were designed for a mounting height of about 30 feet and the light distribution patterns provided reasonable uniform brightness over a relatively large area of pavement as seen from a position (on the pavement) about 300 feet from either side of the luminaire.

Fifty years later, contemporary versions of the first asymmetric, twin-beam luminaires are still accepted as a standard lighting technique for all types of roadways. However, it should be noted that although two-way traffic routes do logically require twin-beam light distribution, single beam light distribution is appropriate for one-way traffic routes. Since the desired objective is to produce the required level of uniform pavement brightness with minimum light output, the portion of the luminaire output that should be eliminated or reduced for one-way streets is the downstream beam rather than the upstream beam. This will be explained in the next section.

5.1.3 Producing Uniform Pavement Brightness

The pavement brightness pattern that could be seen from a helicopter directly above a luminaire, would resemble the luminaires' illumination (isolux) pattern. However, when the pavement brightness pattern is seen by a pedestrian or driver from a position about 300 feet from a street light, there is no simple relationship between the illumination levels at each point on the pavement and the brightness perceived at the same points on the pavement. This is because the directional pavement reflectance (luminance coefficient or reflectance coefficient) varies with the direction of incident light (illumination). For example, light falling straight down on blacktop pavement is reflected from the pavement rather poorly toward the observer's eyes, about 9% directional reflectance. But upstream light easily reflects at a grazing angle towards the observer's eyes. In other words, the directional reflectance for grazing angle upstream light can greatly exceed 9% and the pavement brightness will be correspondingly greater. Upstream lighting, therefore, can provide improved visual effectiveness and energy efficiency on one-way traffic routes. Furthermore, since the effective reflectance of blacktop pavement for downstream lighting is less than 9%, downstream light is relatively ineffective in producing pavement brightness. 1,2,3,4

Because this phenomenon is still not widely understood, some street lighting specialists assume that theoretically ideal street lighting should produce perfectly uniform pavement illumination. However, if a conventional layout of twin-beam street lights did provide perfectly uniform pavement illumination, the pavement would appear much brighter between poles than directly under the luminaires because of the difference in effective pavement reflectances.

Fortunately, in the application of standard twin-beam street lights, only unusual layout geometry can produce excessive pavement brightness between luminaires. That is because conventional luminaires have been designed to produce appropriately nonuniform illumination. Furthermore, since spacing to mounting height ratios and illumination criteria were established by common practice, it is, for all practical purposes, impossible to create excessive illumination between poles.

It is unfortunate that the illumination criteria for roadway lighting do not indicate that the illumination levels must be appropriately nonuniform to produce uniform pavement brightness as seen by the driver. The implication has been that it would be desirable to have illumination uniformity ratios significantly more uniform than those already recommended.

5.1.4 Downstream Lighting

The possibility of reducing direct glare from street lights on one-way streets, freeways and divided highways (with relatively wide median areas) has prompted some street lighting specialists to experiment with downstream lighting. 5,7 Luminaire glare for the oncoming driver can obviously be reduced to a minimum. However, the problem with this approach is that the payement luminance (photometric brightness) created by downstream light distribution is low relative to the footcandle levels produced on the roadway. Direct lighting effects dominate this type of roadway lighting. Vehicles and pedestrians tend to loom up suddenly against the relatively dark pavement when they pass through the downstream beam. Although it is possible to design a street lighting system of the downstream type that produces reasonably good visibility of the traffic itself, the pavement will not be bright enough to be easily seen from a distance, and the luminaires themselves will provide little or no beacon effect (optical guidance). However, in the opinion of the authors, downstream lighting is deficient, principally because it ignores the silhouette effect caused by pavement brightness.

5.1.5 Luminaire Glare

The question naturally arises that if it is desirable to reduce luminaire glare, then why doesn't the upstream beam produce excessive glare? It is true that asymmetric, twin-beam street lights of the conventional refractor type can provide extreme glare if they are set up for long distribution. However, the trend today is to set the lamp position in ANSI/IES Type II or III roadway luminaires to provide medium distribution. This means that there is relatively little light directed towards the observer's eye at a projected vertical angle greater than 80 degrees. As viewed from a distance, luminaires set up in this way are not intolerably glaring, even though it is true that luminaires with sharp cutoff at 75 or 70 degrees would produce even less glare.

The choice of 80, 75, or 70 degree cutoff is based on economics. Seventy degree sharp cutoff is visually ideal since any automobile's roofline would then shield the driver's eye from the main beam. However, the spacing to mounting height ratio for 70 degree sharp cutoff luminaires should not exceed 3 to 1 if good uniformity of pavement luminance is the objective. This ratio increases to about 5 to 1 for 75 degree sharp cutoff luminaires. This ratio would also include 80 degree normal cutoff luminaires since they both have their main beams at approximately the same projected vertical angle.

5.1.6 Visibility of Traffic Route

As noted before, the traffic route is seen by virtue of its luminance, not the level of illumination on the pavement. It is often forgotten that it is just as important to be able to see the direction and other characteristics of the traffic route (pavement) from a good distance ahead, as it is to see the traffic.

5.1.7 The Beacon Effect

The beacon effect (optical guidance) provided by luminaires used along a traffic route can also show the direction of the route and give advance warning of critical areas. Therefore, a delineating glow (not glare) from luminaires is desirable.

5.2 Partial Interchange Task Lighting Concept

5.2.1 Accent Lighting at Critical Areas

The intersection is the critical area where the greatest number of traffic events occur and where safety problems are the greatest. Lighting an intersection serves to reveal traffic conflicts. Even when the intersection is totally unoccupied by traffic, it is important to identify the critical area ahead to the oncoming driver.

Other critical areas include pedestrian crosswalks between intersections, entrances to commercial and business centers, entrances to parking areas, special turn lanes, on/off ramps, merging areas, etc. These critical areas

require accent lighting where the levels of lighting are higher than between the critical areas (continuous lighting or none). Some roadway lighting specialists believe that continuous roadway lighting between critical areas does reduce visual awareness of these critical areas, and therefore, reduces overall traffic safety. The merits of lighting the full length of a high speed roadway have proponents on both sides of the debate, but it is nevertheless true that the critical areas on roadways do require accent lighting. This accent lighting can either be higher levels of illumination for a continuously lighted roadway or a single luminaire at the critical area for a roadway that is not continuously lighted.

5.2.2 Visual Task Zones on Roadway Interchanges

On freeways and expressways, dangerous high speed intersections are replaced by interchanges with on/off ramps, merging and diverging areas, and ramp connections with the crossroad. It should be noted that all of these roadway elements carry one-way traffic. Another important characteristic of these roadway elements is that the hazardous points and traffic conflict areas are limited to relatively narrow visual task zones.

For example, the traffic conflicts between the on-ramp and the adjacent through lane occur over a relatively long but narrow area. The point of ultimate traffic conflict is the point where narrowing of the on-ramp forces on-ramp traffic to merge with the freeway lane. However, since traffic can merge at any point along the entire on-ramp acceleration lane, the full length of this lane, up to the point where it narrows, can determine the length of the visual task zone which is two lanes in width. At an off-ramp, the visual task zone includes the critical area just beyond the off-ramp nose up to the point where the off-ramp deceleration lane begins. In order to conserve energy, the lighting of an on/off ramp is often limited to a single luminaire at the ultimate conflict point.

Freeway design practice in the State of California and many other states, emphasizes the need for lighting at these critical areas (so called "partial interchange lighting"). The objective of partial interchange lighting is

^{*} Adjacent through lane and the off/on ramp.

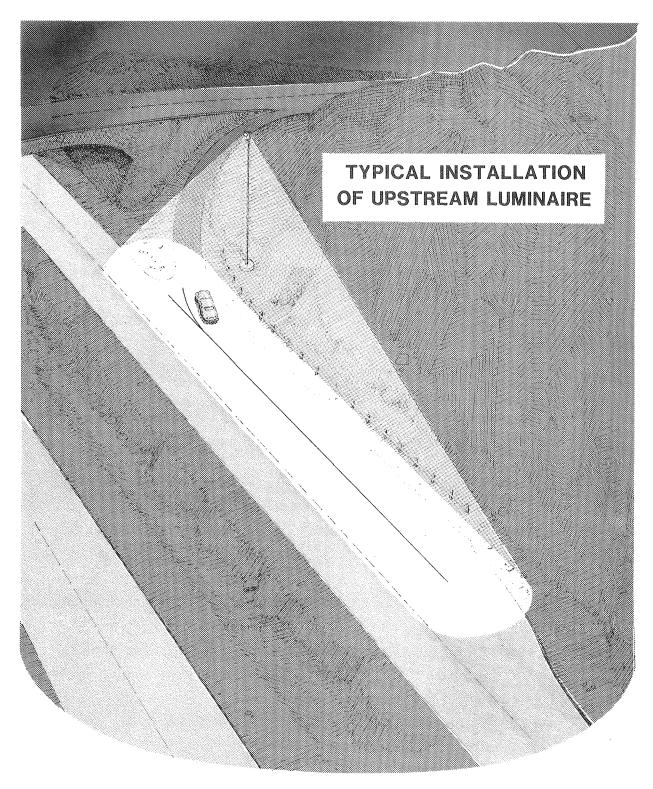
to put light where it is most needed, to reduce the installed cost of the lighting, and to conserve energy. At the present time, the State of California would not ordinarily provide continuous lighting of interchanges or of the roadway between interchanges even in urban areas. The Federal Highway Administration also emphasizes the need for the lighting of these critical areas and considers that continuous lighting may be warranted only when traffic volumes are usually high.

Although federal and many state highway design standards emphasize the lighting of critical areas on freeways (partial interchange lighting), they have not gone so far as to limit lighting to relatively narrow visual task zones or to specify the use of upstream lunimaires. This is because conventional twin-beam street lights have been adopted as a standard for freeway lighting. However, more energy can be saved by further limiting lighting to specific visual task zones within critical areas. Furthermore, since these visual task zones exist on one-way roadways, it is desirable to take advantage of the greater efficiency of upstream light distribution in order to produce better sight with less light. The concept of task lighting a roadway off-ramp with an upstream luminaire is shown in Figure 5.

5.3 Upstream Roadway Interchange Luminaire Design

5.3.1 A Theoretically Ideal Solution

It is instructive to imagine a theoretically ideal pavement lighting technique for a visual task zone. First of all, the pavement should have perfectly uniform brightness as seen by oncoming drivers. Furthermore, assuming that brightnesses in the surrounding environment are relatively low, as they would be at remote roadway interchanges, the pavement luminance level may be as low as 0.03 footlamberts. This is about 15 times the level created on black top pavement by the full moon directly overhead on a clear night. The 0.03 footlambert value is typical of the maintained pavement luminance achieved (between luminaires) when Type III conventional twin-beam street lights with 200-watt high pressure sodium lamps are used on 30-foot poles at about 5 to 1 spacing to mounting height ratios.



The pavement luminance levels created by 200-watt high pressure sodium twin-beam luminaires are comparable to the levels created by luminaires of the same type using 400-watt clear bulb, mercury lamps. Since the 400-watt clear bulb, mercury luminaire was widely used for partial interchange lighting, the change to the same type of luminaire using 200-watt high pressure sodium lamps has not compromised lighting levels while it has somewhat improved glare control characteristics. Although 400-watt high pressure sodium luminaires have been used in some cases for this same application, it is generally considered by the Federal Highway Administration that 200-watt high pressure sodium, twin-beam liminaires provide adequate pavement luminance for roadways.

In any case, the 0.03 footlambert level for perfectly uniform pavement luminance can be considered to be an energy conserving level that would be appropriate for a theoretically ideal lighting technique.

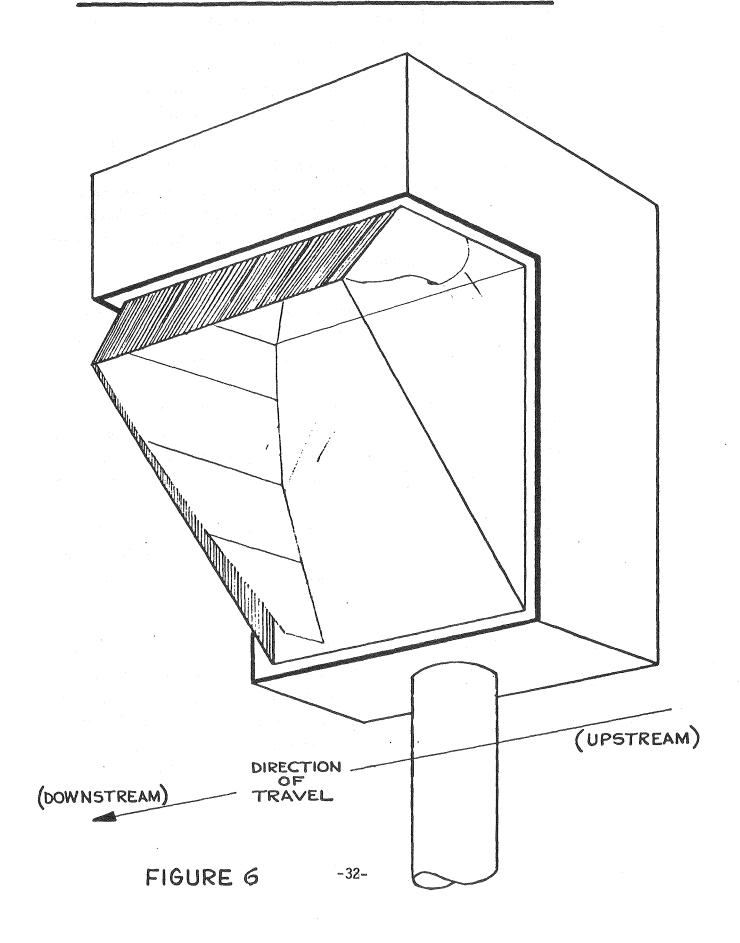
A theoretically ideal lighting technique for a one-way traffic route should produce perfectly uniform pavement brightness as seen by oncoming drivers while the pavement should appear black from the air and when viewed from the opposite direction. There is no practical way that such an extraordinary lighting feat can be achieved at this time, but if it could be done it would be a way of producing maximum silhouette effect (and therefore, outstanding visibility of traffic and the traffic route itself) without producing sky glow or wasted light in the opposite direction.

This theoretically ideal freeway lighting should, of course, be limited to the visual task zone. The visual task zone would then be precisely delineated and no light would be wasted beyond the visual task zone. If theoretically ideal lighting of this type could actually be developed for one-way traffic routes, the electric lighting power density (watts/sq. ft.) consumed by such a system would be extraordinarily low.

5.3.2 Upstream Luminaire Design

The initial prototype (Figure 6) was successful in establishing the advantages of upstream luminaires for visual task zones for lighting

UPSTREAM LUMINAIRE

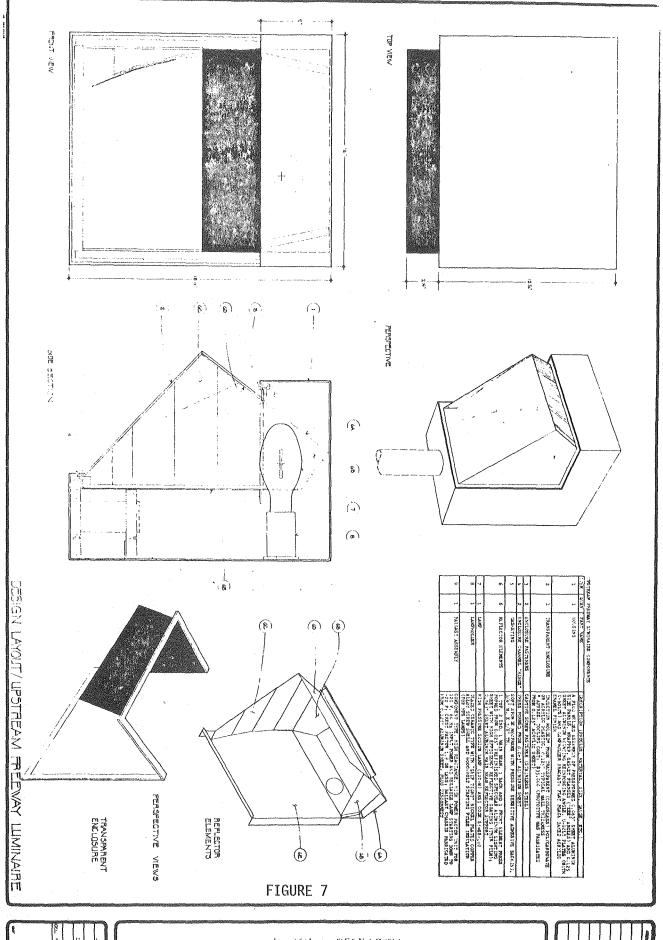


roadway interchanges. However, there was only a limited amount of time available for the development of this prototype. Therefore, the refinements and design changes generally needed to optimize the performance of new and unusual luminaires were not accomplished during this project. This is an area for future development in order to maximize the design's performance.

The housing of the prototype upstream luminaire (see print, Figure 7) was fabricated from 0.080" thick sheet aluminum and was designed to provide generous rain drip flanging and gasketing space. The housing has a high strength to weight ratio. Its dimensions are 16 inches wide, 15 inches deep and 18 inches high. A compartment behind the vertical rear reflector contains a fitter for a 2-inch standard pipe post top tenon. This compartment also provides space (well removed from lamp heat) for the lamp ballast. Two sets of reflector elements were fabricated from flat .025" Coilzak specular lighting sheets. One set had OCLI's enhanced high reflector optical thin film coating and the other set did not.

The light transmitting enclosure was fabricated from 1/8" thick, transparent acrylic plastic. Since there are no external prisms as with refractor luminaires, the dirt depreciation factor will be favorable. The slope of each face of the transparent enclosure is critical to prevent the reflection of lamp images off the transparent enclosure surfaces from being reflected in directions that cause glare or spill light. Although the front panel in the prototype was properly sloped, it was determined that the upstream (side) panel should also be sloped rather than vertical. If a unit of this type were to go into production, the transparent enclosure should be injection molded in order to achieve the shape required to eliminate the adverse effects of internal reflections.

A clear bulb, high pressure sodium lamp was chosen because of its compact arc tube and its relatively high efficacy. Although low pressure sodium lamps would provide more lamp lumens per watt, the large dimensions of these lamps would, for all practical purposes, make it impossible to confine light to the narrow visual task zone. Where a high degree of light control is required in a luminaire of practical size, a very compact light source is needed.



FOURT HIBS PHIS, CHILD BAT HAFASI CALIFORNIA DON 418 A184 A18A 418 AUD DEVELOPMENT, INC. -34-



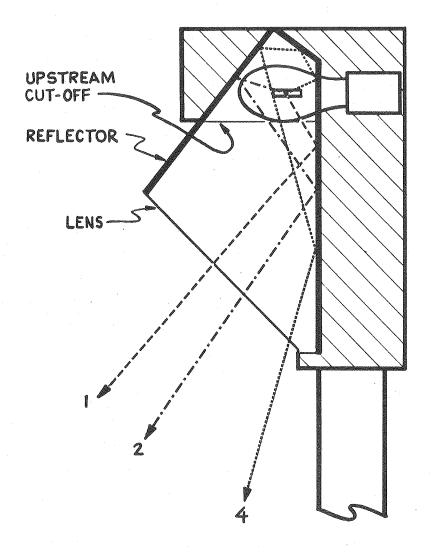
5.3.3 Light Performance Objectives

The design objective was to achieve the desired pavement luminance with a 70 or 100-watt high pressure sodium lamp. Another objective was to have sharp cutoff of all light above a vertical angle of about 76 degrees. The cutoff characteristics of the luminaire developed can easily be improved to the point where cutoff of glare will be essentially eliminated above 80 degrees, but the 76 degree objective will be difficult to achieve. Sharp cutoff of glare can be achieved in a luminaire of this type because light control is developed by using specular reflectors and an optically clear acrylic enclosure without prisms or other surface configurations. When a typical refractor and reflector control system are combined, they interact in a way that produces stray light and true sharp cutoff performance is not achieved.

A major problem in the design of the upstream luminaire is that much of the lamp output must be directed to a relatively narrow visual task zone. To accomplish this "tight" light control, multiple reflections are inherently involved. Figure 8 shows the side view cross section of the luminaire with examples of how multiple reflections are utilized to direct the light rays to the visual task zone. Examples of single and multiple reflections are shown. The luminaire is positioned (in Figure 8) as you would see it, approaching it in a car. It is suggested that Figures 5, 6, and 7 be reviewed again to assist the reader in visualizing how the luminaire is positioned in Figure 8. The line under the lamp identified as "upstream cut-off" shows the bottom of a reflector within the luminaire housing which shields the lamp from on-coming traffic.

Twin-beam street lights of the refractor type typically have a streetside coefficient of utilization of about 0.50, but this includes both the upstream and downstream beams. One objective in the design of the upstream freeway luminaire was to achieve a comparable 0.50 streetside CU in the upstream quadrant only. Another objective was to produce reasonably uniform pavement luminance 0.03 footlambert minimum maintained (0.05 footlambert

DESIGN UTILIZING MULTIPLE REFLECTIONS



SIDE VIEW SECTION *

FIGURE 8
*AS SEEN BY APPROACHING DRIVER

minimum initial) in the upstream visual task zone for a longitudinal distance of about 4 mounting heights. Since the mounting height chosen for this luminaire was 40 feet, this means that the longitudinal spacing-to-mounting height ratios of these luminaires should be about 4 to 1, or a distance of 160 feet. This is an economically feasible spacing, which is comparable to the spacing used with twin-beam luminaires in partial interchange lighting. It should be emphasized that with partial interchange lighting, a single luminaire may be used by itself at each critical area.

It has been common practice to consider that spill light is of some value in revealing vehicles beyond critical areas (stopped on shoulder or right-of-way areas, etc.). But the principles of energy conservation now require that we be more precise about defining the areas that have the greatest need for lighting. Therefore, the principal objective in the design of the upstream luminaire was to provide lighting where it is most needed (with minimum consumption of electrical power). That is, light should be distributed only to the visual task zone.

Since upstream luminaires may be located slightly in advance of the off-ramp noses, the prototype luminaire provided a limited downstream beam which served the purpose of providing direct illumination of the nose curb (Figure 5).

5.4 Upstream Luminaire Performance

5.4.1 Photometric Tests

Environmental Research Laboratories in Scottsdale, Arizona performed the photometric tests. Four tests were made using 70 and 100 watt high pressure sodium lamps with two sets of identical reflector elements, one with OCLI coating and one without. The certified test reports are in the appendix (ERL 3437, 3458, 3470, and 3471). The photometric data for the twin-beam refractor-type luminaire used for comparison was taken from past tests run in ERL (ERL 3263) for a high quality Type II luminaire using a 200 watt high pressure sodium lamp.

Standard computer programs are based on luminaires with symmetrical "street side" light distribution. Therefore, to accommodate the upstream luminaires, special procedures were devised to process the data using the existing program. In the future, new computer programs will be needed to process the data of upstream type luminaires.

Since the study is based on pavement luminance, there was little need to present the typical footcandle data in this report except for coefficient of utilization to show the improvement in upstream task zone lighting (Table 9).

5.4.2 Spill Light

The prototype upstream luminaire did distribute some light to the shoulder and the through lanes adjacent to the visual task zone. There is a tendency to rationalize the existence of this spill light in accordance with traditional reasoning. However, it is more logical to state that such spill light should have been distributed to the visual task zone, thereby allowing the use of a lower wattage lamp. It should be possible with design refinements to satisfy the design criteria using a 70-watt, rather than a 100-watt, high pressure sodium lamp.

5.4.3 Pavement Luminance Study

The candlepower data from the photometric tests were used to develop pavement luminance (brightness) data for the visual task zone. The pavement luminance computer printouts; for the 100-watt high pressure sodium upstream luminaire with coated reflector is in Table 4, for the 200-watt conventional twin-beam luminaire is in Table 5, and for 100-watt upstream luminaire without coated reflector is in Table 6. The task zone for the computer study was defined as an area two lanes wide (off-ramp and one through lane) beginning at the luminaire (Y=0) and going upstream 156 ft. (Y=156). Because of the problems of processing the data using existing computer programs, the downstream beam used to illuminate the nose curb was not included.

LIGHTING RESCARCH AND DEVELOPMENT NO. 4 JOSEPH COURT SAW RAFALL, CA 94901

REPORT NO.1026 COMPUTED USING THE FOLLOWING PHOTOMETRIC TEST REPORT(S): ERL 3458

UPSTREAM DIRECTIONAL LUMINAIRE - BEAM SIDE COATED REFLECTUR, 100-W HPG, 40 FT, MOUNTING HT. LIGHT LOSS FACTOR = 1.00

** PAVEMENT LUMINANCE LEVELS(FOOTLAMBERTS) FOR R3 CIE ROAD SURFACE **

VALUES ARE STATUTE (1 DEGREE VIEWING ANGLE) NORMALIZED TO A Q-ZERO VALUE OF 0.07 LOCATION OF OBSERVER IS X = 20.0 Y = 300.0

	LOCATION OF OBSERVER 18 X = 20.0 Y = 300.0	
Y CO-ORD FEET		
156.0	+ + + + + + 0.10 0.16 0.09 0.05 0.03	
150.0	+ + + + + 0.12 0.17 0.10 0.06 0.03	
144.0	+ + + + + 0.14 0.18 0.11 0.06 0.04	
138.0	+ + + + + 0.17 0.19 0.12 0.07 0.04	
132.0	+ + + + + + WEIGHTEN AVG. = 0.14 0.20 0.20 0.13 0.07 0.04	
124.0	MAXIMUM FOOTLAMBERTS = 0.33 + + + + + 0.23 0.22 0.13 0.08 0.05 MINIMUM FOOTLAMBERTS = 0.03	
120.0	† † † † † † 0.26 0.22 0.14 0.08 0.06	
114.0	+ + + + + 0.27 0.22 0.14 0.08 0.06	
108.0	+ + + + + + 0.29 0.23 0.14 0.08 0.06	
102.0	+ + + + + 0.29 0.23 0.14 0.09 0.06	
96.0	+ + + + + 0.30 0.23 0.14 0.09 0.06	
90.0	+ + + + + + 0.32 0.21 0.15 0.09 0.06	
84.0	+ + + + + 0.33 0.23 0.14 0.09 0.06	
78.0	+ + + + + + 0.30 0.21 0.14 0.10 2.07	
72.0	+ + + + + 0.30 0.20 0.15 0.10 0.08	
66.0	0.31 0.20 0.15 0.10 0.09	
	+ + + + + 0.30 0.21 0.16 0.12 0.09	
54.0	0.27 0.20 0.13 0.10 0.0B	
48.0	0.22 0.17 0.12 0.11 0.07	
42.0	0.20 0.15 0.12 0.10 0.08	
36.0	0.18 0.14 0.12 0.10 0.08 TABLE 4	
30.0	0.14 0.11 0.10 0.08 0.08	
24.0	1 + + + + + 5 0.14 0.13 0.15 0.10 0.08	
18.0	(+ + + + + + + + + + + + + + + + + + +	
12.0	0.14 0.13 0.15 0.10 0.08 4	
	0.09 0.11 0.11 0.08 0.06	
0.0	t t t t t t t t t t t v.08 0.09 0.11 0.08 0.05	
	•	

0.0 6.0 12.0 18.0 24.0

REPORT NO.1039 COMPUTED USING THE FOLLOWING PHOTOMETRIC TEST REPORT(S): ERL 3263

TYPICAL TWIN-BEAM CTYPE 11-MSC) REPRACTOR LUMINAIRE 200 W HPS, 40 FT. MOUNTING HT. LIGHT LUSS FACTOR = 1.00

0.24

** PAVEMENT LUMINANCE LEVELS(FOOTLAMBERIS) FOR R3 CIE ROAD SURFACE **

VALUES ARE STATIC(1 DEGREE VIEWING ANGLE) BORMALIZED TO A Q-ZERO VALUE OF 0.07 LOCATION OF OBSERVER IS $X=-\xi 0.0$ (=-300.0

Y CO-ORD. FEET		
156.0	+ + + + + + 0.03 0.08 0.13 0.03 0.05	
150.0	+ + + + + + 0.04 0.10 0.14 0.09 0.06	
144.0	+ + + + + + 0.05 0.12 0.15 0.10 0.06	
138.0	+ + + + + + 0.06 0.14 0.17 0.11 0.07	WEIGHTED AVG. = MAXIMUM FOOTLAMBERTS =
132.0	+ + + + + + 0.07 0.16 0.18 0.12 0.08	MINIMUM FOU LAMBERTS =
126.0	+ + + + + + + + + + + + + + + + + + +	
120.0	+ + + + + + 0.10 0.21 0.22 0.15 0.10	
114.0	+ + + + + + + + + + + + + + + + + + +	
108.0	+ + + + + + + + + + + + + + + + + + +	
102.0	+ + + + + + 0.18 0.31 0.30 0.20 0.15	
96.0	+ + + + + + + + + + + + + + + + + + +	
90.0	+ + + + + + 0.26 0.39 0.36 0.25 0.20	
84.0	+ + + + + + 0.29 0.42 0.40 0.29 0.22	•
78.0	+ + + + + + 0.30 0.42 0.39 0.30 0.23	
72.0	+ + + + + + + + + + + + + + + + + + +	
66.0	+ + + + + + 0.30 0.40 0.34 0.31 0.26	
60.0	+ + + + + + 0.29 0.37 0.30 0.31 0.25	
54.0	0.28 0.35 0.29 0.30 0.25	
48.0	+ + + + + + + + + 0.28 0.34 0.31 0.30 0.25	TABLE 5
42.0	0.27 0.33 0.31 0.30 0.25	7
36.0	+ + + + + + 0.26 0.31 0.30 0.30 0.26	
30.0	0.26 0.29 0.29 0.29 0.25	
24.0	0.24 0.26 0.26 0.28 0.24	
0.0 15.0 0.81 FSTREAM	+ + + + + + 0.20 0.22 0.25 0.26 0.25	
12.0 X	+ + + + + + + + + + + + + + + + + + +	
ر ۱۰۰۰	0.17 0.16 0.18 0.19 0.19	
. (),()	0.15 0.15 0.16 0.16 0.17	

0.0 6.0 12.0 18.0 24.0

L]OHIDE PESEURCH RUB DEVELORMENT NO. 4 OBERTH COURT SAN PARAEL, CA (14901

REPORT NO. 1028 COMPUTED USING THE FOLLOWING PHOTONETRIC TEST REPORT/S:: ERE 34/0

UPSTREAM DIRECTIONAL LUMINAIRE - REAM 51DE UNCOATED REFLECTOR, 100-W HPS, 40 FT, MOUNTING HY. LIGHT LOSS FACTOR = 1.00

** PAVEMENT LUMINANCE LEVELSYSGOTLAMBERIS) FOR R3 CIE ROAD SURFACE **

VALUES ARE STATIC(1 BEGREE VIEWING ANGLE) NORMALIZED TO A 0-2ERO VALUE OF 0.07

LOCATION OF OBSERVER IS X = 20.0 Y = 300.0

Y CO-ORO. FEET			
156.0	0.09 0.13 0.0	7 0.04 0.03	
150.0	+ + + 0.10 0.14 0.0	+ + 8 0.05 0.03	
144.0	0.12 0.14 0.0	+ + 9 0.05 0.03	
138.0	† † † 0.14 0.15 0.1	0 0.06 0.04	weighted aug. = 0.11 maximum footlamberts = 0.26
132.0	+ + + 0.16 0.16 0.1	1 0.06 0.04	MINIMUM FOOTLANDER'S = 0.03
126.0	+ + + 0.18 0.17 0.1	+ + + 1 1 0.07 0.05	
120.0	+ + + 0.20 0.17 0.1	† † 1 0.07 0.05	
114.0	t t t 0.22 0.18 0.1	† † 1 0.07 0.05	
108.0	0.24 0.18 0.1	1 0.07 0.06	
102.0	† † † † 0.25 0.19 0.1	1 9.08 0.06	
96.0	0.26 0.19 0.1	2 0.08 0.05	
× 90.0	0.25 0.19 0.1	2 0.08 0.05	
84.0	0.23 0.18 0.1	1 0.08 0.05	
78.0	+ + + 0.22 0.17 0.1	1 0.03 0.06	
72.0	0.23 0.17 0.1	2 0.08 0.06	
66.0	0.24 0.17 0.1	3 0.09 0.07	
60.0	0.23 0.16 0.1	1 0.09 0.07	
54.0	0.22 0.15 0.1	1 0.09 0.06	and the second of the second
42.0	0.19 0.13 0.1	1,0,09 0,06	
36.0	0.18 0.12 0.1	1 0.09 0.07	TABLE 6
30.0	0.16 0.13 0.1		
24.0	0.13 0.10 0.0		
-	+ + + 0.12 0.11 0.1 + + + 0.12 0.14 0.1		
18.0 H H 12.0 K N N		+ +	
8.0 J.	+ + + 0.12 0.14 0.1 + + + 0.09 0.10 0.1	3 0.10 0.06	
0.0 +	1 + +	+ +	
	0.07 0.08 0.0	9 0.07 0.05	

0.0 6.0 12.0 18.0 24.0

The twin-beam luminaire is positioned over the outside edge of the off-ramp lane at Y=0 and X=0. This is standard practice for twin-beam luminaires. The upstream luminaire, however, is 12 feet from the edge of the travelled way in accordance with the proposal to install poles behind guard rails at critical areas on the Dulles Airport Freeway (Washington, D.C.) Thus, the twin-beam luminaire would have to be mounted on a mastarm on a heavy gauge, pole, whereas the upstream luminaire is designed to be mounted at the top of the lighter pole. The upstream luminaire may be tilted to align the main beam with the opposite side of the freeway. This is feasible because the lateral throw of the upstream luminaire fades out relatively rapidly beyond the visual task zone.

It should be noted that the Type II twin-beam luminaire chosen for comparison has a particularly long and narrow pattern. Although a wider and shorter Type III pattern is ordinarily used for partial interchange lighting at freeways, this type of distribution is not appropriate for the lighting of visual task zones. Therefore, although this fact was unforeseen, a legitimate comparison can only be made to a high quality Type II twin-beam luminaire. This pavement luminance study, therefore, also establishes that a twin-beam refractor-type luminaire with good Type II-MSC distribution (using a 200-watt HPS lamp) can also provide reasonably efficient lighting of visual task zones. However, a fully developed upstream luminaire should be able to do the same lighting job using only a 70-watt HPS lamp.

Although it is difficult to draw general conclusions from the comparison of a multitude of printout values that vary in different ways over a given area, some general statements can be made.

For comparison, the end and mid-point "Y" coordinates from the luminance level printouts have been summarized in Tables 7 and 8.

Table 7

156 ft. "Y" Coordinate

Pavement Luminance Levels

Footlamberts

<u>Luminaire</u>	"X" Coordinate					
(HPS Lamp)	0 ft.	6 ft.	12 ft.	18 ft.	<u>24 ft.</u>	
100-Watt Coated Prototype	.10	.16	.09	.05	.03	
200-Watt Type II MSC	.03	.08	.13	.08	. 05	
100-Watt Uncoated Prototype	.09	.13	.07	.04	.03	
		off ramp	*	through lane		

The 100-watt coated upstream prototype was comparable in performance at 156 feet (Table 7) to the 200-watt Type II MSC twin-beam. Both failed to meet the 0.05 fL criterion at one edge, but the 100-watt coated prototype maintained higher levels in the off-ramp lanes (0 to 12 ft.) which is considered more desirable than if the higher levels were in the through lane (12-24 ft.). The uncoated 100-watt prototype has a similar lateral distribution as the 100-watt coated prototype, but lower luminance levels. The difference in luminance levels between these two is greater than what is indicated by the values at the 156 ft. points. For one thing, the computer rounds off to two places (0.00) so for values below 0.10 comparisons are not significant due to rounding errors. But more importantly, the weighted average of the luminance levels (see Tables 4 and 6) for the coated prototype was 27% better (.14 vs. .11) than the uncoated prototype.

The maximum luminance levels occurred in the midsection of the task zone and are summarized in Table 8 (printout data "Y" coordinate at 84 ft.).

Table 8

84 ft. "Y" Coordinate

Pavement Luminance Levels

Footlamberts

<u>Luminaire</u>	"X" Coordinate				
(HPS Lamp)	0 ft.	<u>6 ft.</u>	12 ft.	<u> 18 ft.</u>	<u>24 ft.</u>
100-Watt Coated Prototype	.33	.23	.14	.09	.06
200-Watt Type II MSC	.29	.43	.40	.29	.23
100-Watt Uncoated Prototype	.23	.18	.11	.08	.05
	K	off ramp	- *	_ through lane	

The 100-watt coated prototype was comparable in performance to the 200-watt Type II MSC twin-beam at this point for the outer part of the off-ramp. The levels fall off for the coated prototype in the through lane, as they did at the 156 ft. "Y" coordinate, but are still in excess of the 0.05 fL criterion. As stated before, the off-ramp lane is the preferred area to maximize the lateral luminance levels. The difference between the coated and uncoated prototype luminaires is more pronounced at these higher levels. The levels for the coated prototype were 12-40% higher than for the uncoated unit.

Compared to the 200-watt twin-beam luminaire, the 100-watt prototype upstream luminaire with optical coatings does provide comparable pavement luminance over the 156 ft. long, 24 ft. wide visual task zone. This was accomplished with 50% less lamp wattage (100 vs. 200 watts) and 57% fewer lumens (the 200-watt lamp has a higher efficacy rating - 110 vs. 95 lumens/watt). With design refinements the minimum initial luminance criterion of 0.05 footlamberts (over the 156 ft. long visual task zone) should be achievable with a 70-watt HPS lamp, as more light can be confined to the visual task zone and uniformity is improved.

The twin-beam luminaire does provide good lateral uniformity over much of the visual task zone while the longitudinal uniformity down the strip between lanes is good for both the prototype and twin-beam luminaires.

With regard to coefficients of utilization (Table 9) the coated upstream prototype provided an unusually high streetside CU of 0.596. This is even more remarkable in that 64 percent of the streetside component (.38) is in the upstream quadrant. By comparison, the uncoated upstream luminaire prototype had a total streetside CU of 0.512.

Table 9

<u>Coefficient of Utilization</u>

Luminaire	Total*		<u>Upst</u>	ream
(HPS Lamp)	House	Street	Street	<u>Task Zone</u>
100-Watt Coated Prototype	. 05	.596	.380	.158
200-Watt Type II MSC	.18	.550	.275	.116
100-Watt Uncoated Prototype	.05	.512	.330	.134

^{*}Includes both upstream and downstream.

The streetside CU for the twin-beam Type II MSC refractor luminaire was 0.55. It should be noted, of course, that 50 percent of the street-side output is in the downstream quadrant. Therefore, even though the first prototype of the upstream luminaire has significant deficiencies, it did increase the CU within the upstream visual task zone to .158 for the coated reflector and .134 for the uncoated reflector in comparison to 0.116 for the twin-beam luminaire. The spill light (House CU's) has been reduced from .18 to .05.

Even with the upstream luminaire, there was a considerable amount of upstream light that was outside the defined task zone. Therefore, design refinements should provide an excellent opportunity utilizing the multiple reflection capabilities of optical coatings to improve the performance of the upstream luminaire so that a 70-watt can be used instead of the 100-watt HPS lamp. The 70-watt prototype photometric data for the coated unit vs. the uncoated prototype is encouraging (70-watt pavement luminance printouts not included in report). The improvement in streetside CU for the coated vs. the uncoated prototype was greater with the 70-watt lamp (21.6%) than with the 100-watt lamp (16.4%).

Table 10
Streetside C.U.

	HPS Lamp		
	100-Watt	70-Watt	
Coated Prototype	.596	.602	
Uncoated Prototype	.512	.495	
Improvement	.084	.107	
%	16.4	21.6	

5.5 Cost Benefit Using Coated Luminaire Component

5.5.1 Manufacturing Costs

The estimated costs for manufacturing the upstream luminaire with and without coated reflector in moderate volume are detailed in Table 11. Cost for the luminaire with the uncoated reflectors is \$125.90. The added cost for the coated reflector is \$9.30 per luminaire based on a coating cost of $$1.55/ft^2$, a 30% passthrough markup and scrap loss.

A 70% manufacturer's markup was used to obtain an estimate for the selling prices of \$214.00 and \$230.00 for the uncoated and coated units respectively.

Table 11

MANUFACTURING COST CALCULATIONS: UPSTREAM LUMINAIRE

					TOTAL	COSTS
			MATERIAL	LABOR	COATED	UNCOATED
I.	LUM	INAIRE MANUFACTURING COSTS				
	Α.	Housing		\$21.00	\$ 21.00	
		Panels (0.063" aluminum sheets)5.93 lbs. @ \$1.12/1b120% passthrough mark-up	\$ 8.43		8.43	
		 Mounting Reinforcing Angle 	.70		.70	
		Z Bars (6, 72" x 1.5")	.70		.70	
		• 4-Bolt Plates (2) & Lamp Holder Bracket	1.00		1.00	
		SUBTOTAL:			\$ 31.83	\$31.83
	В.	Transparent Plastic Enclosure	\$ 8.50	500k 500 500 450	\$ 8.50	8.50
		Injection molded (tooling costs \$35,000)				
	С.	Reflector Elements (6)	\$ 5.81	\$11.00	\$ 16.81	\$16.81
		Coilzak lighting sheet,\$0.745/ft.² (5000 lb. price) 6 ft.² including drop, 30% passthrough markup.				·
		<pre>OCLI Coating (one side) \$1.55/ft.² (10,000 ft.² price)</pre>	\$ 9.30		\$ 9.30	
		SUBTOTAL:			\$ 34.61	\$16.81
					(contin	nued)

TABLE 11 (Cont.)

MANUFACTURING COST CALCULATIONS: UPSTREAM LUMINAIRE

			<u>OEI</u>	M COSTS	TOTAL	COSTS
Ι.	LUMINAIRE MFG. COSTS (Cont.)		MATERIAL	LABOR	COATED	UNCOATED
	D. <u>Assembly</u>					
	Fasteners, Hinge and Gask	ets	\$ 3.50	\$ 2.00	\$ 5.50	
	Lamp Holder		1.75	.50	2.25	
	Ballast		37.00	4.00	41.00	
	<pre>Assembly</pre>			10.00	10.00	
	Painting		5.00		5.00	
	Packaging		5.00		5.00	
		SUBTOTAL:			\$ 68.75	\$ 68.75
	ТОТ	AL MANUFACTURING COST:			\$135.20	\$ <u>125.90</u>
			· · · · · · · · · · · · · · · · · · ·			
	E. OEM Selling Price			e de la companya de l		
	(70% Mark-up)				\$230.00	\$214.00

TABLE 12

INSTALLED COST COMPARISON: UPSTREAM LUMINAIRE VS. STANDARD REFRACTOR

I.	LUMINAIRE FIELD ASSEMBLY COST			TOTAL COATED	OSTS UNCOATED
	A. <u>Upstream Luminaire</u>				
	o Upstream Freeway Luminaire (selling price)		\$230.00	\$214.00
	o Lamp (100 or 70-watt HPS)			35.00	35.00
	NET COST:			\$265.00	\$249.00
		(6%), CONTRACTOR'S MARK-UI hour @ \$40.00):	9 (40%),	168.00	161.00
	INSTALLED	COST: (each)		\$433.00	\$410.00
	PRICE DIF	FERENCE		\$23.	00
	B. Standard Refractor Luminaire				
	o 200-watt HPS INSTALLED (Typical installed cost for luminaire, including lamp, labor, equipment, overhead	standard refractor ballast, plus assembly,		\$188.00	
II.	TOTAL INSTALLED COST		STANDARD	NEW DES UNCOATED	IGN COATED
	Luminaire Field Assembly Cost		\$ 188.00	\$ 410.00	\$ 433.00
	Pole and Electrical System Installa		2200.00	2100.00*	2100.00*
	(40-ft. galvanized steel pole wi mastarm on 2" x 2" x 5" concret with 1" conduit run of 200 ft. trenchable earth, plus service equipment, wiring, etc.)	e foundation TOTAL: in <u>easily</u>	\$2388.00	\$2510.00	\$2533.00
	*Same as Standard Refractor except	no mastarm			

5.5.2 Installed Cost Comparison: Upstream Luminaire Vs. Standard Refractor

Cost estimates for the installation of the upstream luminaire and a standard refractor luminaire at a typical roadway interchange are detailed in Table 12. The upstream luminaire is more than double the cost of a standard refractor after installation on the pole, \$433 for the coated unit vs. \$188 for the twin-beam refractor. But when the pole and electrical system costs are included, the difference in costs between the two is only 6%. The added cost for the coated upstream luminaire vs. the standard refractor is \$145 (\$2,533 vs. \$2,388 total installation). This is because the pole and electrical system represent more than 80% of the total installed cost and the upstream luminaire does not use a mastarm (it is mounted on the pole).

The added cost for the coated upstream luminaire vs. the uncoated is only \$23 (\$2,533 vs \$2,510 total installation).

5.5.3 Economic Analysis

The annual electrical costs for the three different luminaires are listed in Table 13. Because of the potential improvements obtained from design refinements, the luminaire with optical coated reflectors uses a 70-watt HPS lamp in these calculations. Two different utility rates are given to show a range that might be encountered in different areas of the country.

Table 13
Annual Electrical Costs

	HPS	Lamp	Annual Elect At 4000	
Luminaire	Rated	20% Ballast Loss	0 4 cents/ KWH	0 12 cents/ KWH
Standard Refractor Uncoated Design Coated Design	200-watt 100-watt 70-watt	240-watt 120-watt 90-watt	\$38.40 19.20 14.40	\$115.20 57.60 43.20

There is an annual savings achieved by using the coated upstream luminaire. It results from lower electrical energy consumption using lower wattage lamps (see Table 13). The same number of luminaires are used at each installation (usually only one unit at each task zone) so the only difference is lower wattage lamps. The savings are listed in Table 14.

Table 14

	Annual Energy	Savings/Luminaire
	@ 4 cents/KWH	@ 12 cents/KWH
Coated Design Vs. Standard Refractor	\$24.00	\$72.00
Coated Design Vs. Uncoated Design	4.80	14.40

Using a simple payback analysis in Table 15, the 70-watt coated upstream luminaire will be cost effective after two years at 12 cents/KWH vs. the 200-watt standard refractor. The payback is six years at 4 cents/KWH.

Table 15

	<u>Payback</u>	
	@ 4 cents/KWH	@ 12 cents/KWH
Coated Design Vs. Standard Refractor	6.0 years	2.0 years
Coated Design Vs. Uncoated Design	4.9 years	1.6 years

5.6 Conclusions

Several equally important factors were involved in the resulting visual effectiveness and energy efficiency of the upstream luminaire. By carefully defining the visual task to be lighted at the critical areas on the freeway, taking advantage of the improved visual effectiveness of the upstream lighting principal (high luminance per unit of illumination), and using optical coated reflectors for precise light control, the required lamp light output was cut in half.

The initial prototype luminaire using coated reflector elements satisfied the lighting criteria using a 100-watt HPS lamp compared to conventional twin beam luminaire with a 200-watt HPS lamp.

With further refinements of the upstream luminaire, it is believed that the lighting criteria can be satisfied using a 70-watt HPS lamp. The savings in energy costs in two years (at 12 cents/KWH) would pay for the added cost for upstream luminaire.

6.0 PHOTOVOLTAIC POWERED REMOTE INTERCHANGE LIGHTING USING UPSTREAM LUMINAIRE

6.1 Photovoltaics

While most photovoltaic power applications have been exotic and unusual (e.g., in space vehicles), they have proven to be cost effective in more down-to-earth applications. For example, navigational aids in harbors and remote weather stations are successfully using photovoltaic power.

In the past, photovoltaic power was not practical for roadway lighting applications. The key reason has been the high cost of the photovoltaic cells. Not too many years ago the cost was approximately \$200.00 for a peak watt.* Recently, prices have been in the \$8.00 - \$10.00 range for a peak watt. Another restrictive factor has been the large surface area requirements because of the low efficiency of the cells. Currently available silicon cells are only able to convert 12 to 14% of the sun's energy (that falls on the cell) into electrical energy.

But things are changing. The upstream luminaire task lighting concept provides opportunities to light remote areas using less than half of the power needed for conventional luminaires while photovoltaic cells are getting cheaper. The cost of utility distributed electric power is also getting more expensive. For example, there are projections that in one or two years the cost of a photovoltaic peak watt will be as low as \$2.00, and DOE is estimating a \$0.50 peak watt in the mid-1980's (along with higher efficiencies for the photovoltaic cells). Installation costs for conventional above-ground power line extensions have greatly increased. Also, an increasing number of local governments require even more expensive underground systems. Therefore, line extensions to freeway luminaires at a remote interchange can be very expensive.

Photovoltaic power systems have proven to have some interesting advantages. They are very reliable. Installations powered by photovoltaic cells are not affected by power line failures, brownouts, peak power demands or rate increases. The cells have no moving parts, nor do they deteriorate.

^{*}A peak watt is the electric power produced by a photovoltaic unit (with l-watt rating) when the sun is directly over the cell on a clear day.

Installations have been operating continuously for over 20 years in very adverse climatic conditions atop mountains or in the ocean as navigational aids. They are still operating at or exceeding their original design ratings. It is important to note that photovoltaic arrays are over-designed to compensate for efficiency losses due to dirt, snow and cloudy days.

6.2 Remote Interchange Installation

Figure 9 shows a rough concept of a photovoltaic power system for an upstream freeway luminaire. The upstream luminaire is shown at the top of a pole and the photovoltaic array (approximately 1.5 square meter in area) is shown lower on the pole. The required batteries and control equipment would be installed in a weather-proof cabinet well off the traveled way. The pole may be aluminum with a frangible or slip base as required by the local highway department. It is desirable to avoid putting the luminaire on a long mastarm because that leads to a significant increase in the mass of the pole and increases the collision hazard.

It should be noted that the direct current power source from the photovoltaic array is particularly suitable for solid-state ballasts. A complication with most solid-state ballasts is that 60 Hz AC power must first be converted into DC power prior to being changed (by the solid-state ballast) to high frequency alternating current (30-50 Khz). This high frequency output is needed because it is then possible to ballast the lamps with a simple capacitor which has essentially zero power loss. Also the lamp efficiency with regard to lumens per watt is increased by a factor of about 10% simply due to the fact that it is operated on high frequency alternating current. For each type of arc discharge lamp there is an optimum frequency of operation. High frequency operation also improves lumen maintenance over conventional ballasts having relatively poor lamp current crest factors. Furthermore, ballast losses can be reduced to less than 10% of arc tube watts (typical input power for a 60 Hz, core and coil ballast). Incidentally, the 50, 70, and 100-watt high pressure sodium lamps are ideal for photovoltaic operation because the open circuit voltage for these lamps is relatively low (about 150-volts, peak open circuit voltage).

ROADWAY PHOTOVOLTAIC SYSTEM

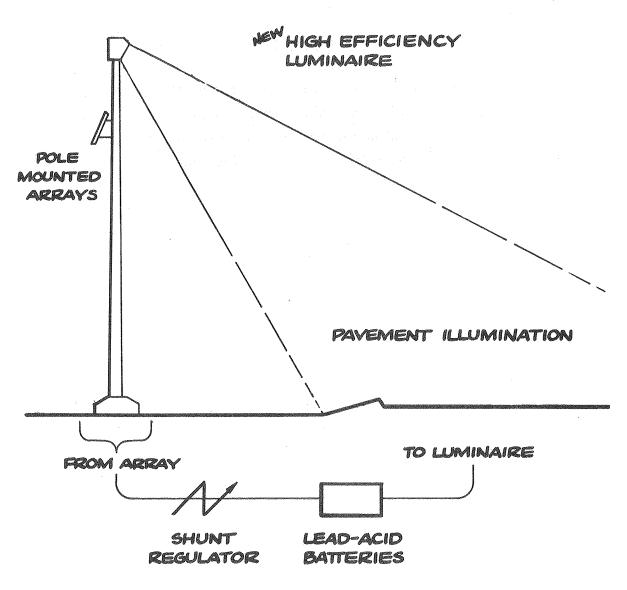


FIGURE 9

6.3 Conclusion

The first stage development of this upstream freeway luminaire concept using optical coated reflectors, has established that upstream lighting of visual task zones on freeways can provide a high degree of visual effectiveness and energy efficiency. Using this upstream luminaire and solid state ballasts makes solar powered roadway lighting in remote areas more feasible.

ACKNOWLEDGMENT

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APPENDIX

TEST RESULTS:

ENVIRONMENTAL RESEARCH LABORATORIES CERTIFIED TEST REPORT NOS. ERL 3458, ERL 3470, ERL 3437, ERL 3471

LIGHTING SCIENCES INC.
CERTIFIED TEST REPORT NOS. LSI 1069, LSI 1072, LSI 1075

ENVIRONMENTAL RESEARCH LABORATORIES

7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK, SCOTTSDALE, ARIZONA 85260 TELEPHONE: (602: 948-3471

CERTIFIED TEST REPORT NO. ERL 3458

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE
COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

REPORT PREPARED FOR:

OCLI, INC. SANTA ROSA, CALIF.

CERTIFIED BY:

16" | 6.5" | 15.2"

DATE: APR 12, 1979

THE ATTACHED REPORT IS BASED UPON 58 PLANE PHOTOMETRY VERTICAL TEST INCREMENTS ARE 2.5 DEGREES.

TEST DISTANCE EXCEEDS 25 FT.

TESTED IN ACCORDANCE WITH IES RECOMMENDED PROCEDURES

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3458

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE
COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

UTILIZATION TABLE

COEFFICIENT OF UTILIZATION

RATIO	HOUSE SIDE	STREET SIDE	TOTAL
KALLO			TOIME
0.5	.048	.272	.320
1.0	.051	.446	.497
1.5	.052	.546	.598
2.0	.052	.572	.624
2.5	.052	.582	.634
3.0	.052	.585	.637
3.5	.052	.588	.640
4.0	.052	.590	.642
5.0	.052	.591	.643
TOTAL:	.053	.596	.649
PERCENT:	5.3	59.6	64.9

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3458

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(BEAM SIDE)

CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	1710	1710	1710	1710	1710	1710	1710	1710	1710	1710
2.5	1854	1869	1955	1990	1917	1822	1727	1698	1681	1686
5.0	1945	1982	2027	1823	1727	1722	1733	1727	1727	1721
7.5	2035	2059	1919	1817	1846	1917	1992	1935	1902	1867
10.0	2745	2757	2361	2246	2189	2053	1986	1975	1984	1995
12.5	3028	2988	2678	2764	2639	2420	2456	2501	2533	2542
15.0	3071	2935	2786	2979	3017	3047	3056	2877	2825	2832
17.5	2980	2816	2822	3110	3118	3586	3602	3235	3140	3129
20.0	2631	2514	2756	3289	3361	3586	3890	3605	3251	3292
22.5	2384	2384	2643	3271	3810	3805	3861	3495	3245	3019
25.0	2228	2278	2583	3366	3958	4432	4301	3460	3367	3106
27.5	2137	2124	2397	3134	3805	3947	4172	3957	3461	3030
30.0	2095	2053	2272	2836	3485	3319	4202	3928	3589	3170
32.5	1981	2088	2248	2741	3088	3272	3914	3934	3461	2879
35.0	1752	2136	2290	2609	3148	3260	3061	3027	2976	2664
37.5	1619	2171	2308	2508	2982	3751	3003	3148	3122	2925
40.0	1571	2195	2278	2496	3242	3887	3232	3553	3636	3507
42.5	1583	2290	2236	2389	3307	3775	3955	3865	3729	3589
45.0	1553	2201	2266	2532	3278	3586	3855	3691	3642	3658
47.5	1493	1976	2224	2586	3106	3503	3602	3853	4389	4438
50.0	1475	1651	1955	2496	2899	3183	3767	4599	4144	4048
52.5	1168	1307	1590	2145	3183	2840	3919	4997	5381	5479
55.0	704	858	1267	1829	3296	2586	4466	5708	5305	5549
57.5	349	408	759	1239	2597	2242	4678	5835	5428	5130
60.0	252	284	592	899	1319	2207	4284	5823	5288	4909
62.5	180	189	334	810	1148	2077	3961	4604	4581	4426
65.0	108	112	197	697	964	2207	3537	4523	4990	5688
67.5	42	47	59	458	656	1946	3144	4720	4967	5025
70.0	36	35	47	220	716	2059	3091	4171	4733	4607
72.5	36	41	59	77	585	1485	3020	3241	4021	4362
75.0	42	41	53	65	384	1177	2615	2790	2959	3298
77.5	24	35	41	59	343	952	1257	1831	2439	2867
80.0	42	59	65	59	313	195	329	577	612	1198
82.5	96	94	107	59	88	195	235	173	326	430
85.0	114	118	119	53	82	165	205	115	198	296
87.5	126	118	137	53	88	142	199	127	169	331
90.0	126	124	143	53	88	153	170	104	64	87

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(BEAM SIDE)

				HOR	IZONTAL	ANGLE				
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT. ANGLE										
	1710	1710	1710	1710	1710	1710	1710	1710	1710	1710
0.0 2.5	1669	1651	1651	1645	1651	1640	1639	1627	1627	1616
5.0	1710	1704	1704	1686	1681	1663	1663	1633	1616	1587
7.5	1832	1803	1763	1716	1692	1658	1633	1609	1586	1552
10.0	2001	1990	1999	1986	1961	1924	1881	1828	1774	1716
12.5	2524	2492	2470	2433	2404	2353	2305	2242	2180	2095
15.0	2827	2807	2742	2632	2579	2545	2571	2556	2503	2369
17.5	3071	2970	2866	2909	2906	2800	2748	2668	2574	2463
20.0	3106	2994	2966	2944	2935	2887	2860	2763	2650	2556
22.5	2891	2807	2641	2615	2614	2481	2358	2296	2203	2107
25.0	2908	2743	2559	2485	2498	2487	2512	2485	2450	2381
27.5	2768	2655	2677	2685	2760	2811	2801	2728	2603	2463
30.0	2896	2807	2807	2744	2556	2382	2364	2284	2174	2077
32.5	2414	2393	2447	2415	2293	2237	2358	2449	2374	2218
35.0	2257	2299	2429	2350	2288	2295	2394	2467	2427	2439
37.5	2966	2889	2972	3073	3052	3188	3231	3142	3032	2906
40.0	3379	3245	2866	3120	3221	3118	3219	3242	3073	2883
42.5	3478	3350	3113	3103	3356	3333	3290	3313	3208	3181
45.0	3810	3846	3703	3573	3373	3385	3355	3396	3426	3542
47.5	3845	3601	3449	3502	3817	3756	3856	3887	3925	3753
50.0	3897	3788	4216	3890	4190	4562	4658	4663	4948	4651
52.5	5264	5066	4871	4695	4821	5020	5295	5331	5706	5142
55.0	4950	4476	4558	4766	5148	5205	5083	5290	5700	4762
57.5	4746	4809	4617	4960	5445	5345	5213	5142	5265	4313
60.0	4403	4494	4688	4895	5264	5530	5342	4905	4689	4044
62.5	4409	4412	4959	5494	6000	6255	6333	5728	5489	4529
65.0	5526	5428	5625	6153	6461	6405	6138	5355	5224	4809
67.5	5427	5457	5997	6617	6881	6881	6710	5461	4895	4511
70.0	4519	5060	5413	5912	6776	6794	6593	5461	4660	4120
72.5	4345	4365	5059	5688	6076	5785	5437	4219	3714	3309
75.0	3757	4114	4676	5541	5650	5374	5006	4012	3737	3472
77.5	3176	3461	3850	3849	3928	3837	4245	3503	2668	2346
80.0	1657	1850	2294	2903	3035	3055	2818	2041	1998	1896
82.5	692	904	955	969	1062	1118	1226	1130	722	478
85.0	325	414	507	640	694	730	1179	1136	746	758
87.5	285	373	660	934	945	1095	1468	1284	1522	1074
90.0	75	99	224	440	811	997	908	816	999	1196

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(BEAM SIDE) CANDLEPOWER TABULATION CONTINUED

15.0 1971 1021 273 204 138 96 54 42 42 17.5 2140 945 368 228 150 60 42 36 36 20.0 2245 974 516 270 66 48 30 24 30	
ANGLE 0.0 1710 1710 1710 1710 1710 1710 1710 1	5.0 180.0
25.0 2018 957 380 270 48 30 30 36 36 27.5 2018 951 386 288 36 42 36 24 24 30.0 1646 624 409 300 36 60 42 24 24 32.5 1721 671 415 342 60 48 24 24 24	710 1710 213 1181 275 246 171 159 134 147 73 73 42 43 36 36 30 30 30 30 30 30 24 24 6 18 24 24
35.0 2035 875 439 354 96 48 42 24 12 37.5 2594 799 463 384 90 24 24 12 6 40.0 2704 805 486 426 54 6 6 6 6 42.5 2989 776 504 444 30 18 6 3 6 6 6 6 6 6 5 5 18 18 18 18 8	24 24 12 12 6 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(OPPOSITE TO BEAM) CANDLEPOWER TABULATION CONTINUED

			HOR	IZONTAL	ANGLE				
67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
1653	1653	1653	1653	1653	1653	1653	1653	1653	1653
1831	1844		1861	1867	1859	1861	1866	1872	1855
1956	1952	1957	1938	1932	1912	1908	1890	1884	1855
2009	1988					1861			1783
2063	2054	2041	2009			1908	1884	1848	1807
	2461	2446	2390			2224	2168	2109	2033
									2545
				3175					2527
			3294	3228		2943			2301
		3371	3282	3098	2882	2610	2352	2139	2063
		3336	2931			2253		2144	2051
						2259			1462
									1028
									784 576
							705	622	559
		1897				3272		639	398 410
		2104						909 405	172
	2132	2434 2215				1301		905	196
						308		237	190
	2150			1147	376	315		237	178
				481		291			113
				309	305	267	177	124	95
987	748	626		285	264	184		100	47
	227	226	231	237	200	142	130	124	71
196	185	173	196	166	141	136	154	100	71
142	143	173	166	154		178		106	71
101	119	125	113			148			23
95		65	142	148		148		65	29
									11
									5
		41	47	59	41	23		- 5	0
		6	5					3	0
			5	0		11	5		0
		11					3	•	. 0
TT	6	TT	11	TT	5	U	U	U	. 0
	1653 1831 19569 2063 24725 3389 3484 3532 2497 2533 2497 2533 2456 1457 2527 2069 1058 1058 1058 1058 1058 1058 1058 1058	1653	1653 1653 1856 1956 1952 1957 2009 1988 1981 2063 2054 2041 2479 2461 2446 2925 2964 2983 3276 3360 3377 3389 3330 3324 3484 3432 3371 3532 3378 3365 2497 2282 2232 2533 2347 2160 2194 1982 1969 1456 1677 1897 1278 1599 2154 1772 2132 2494 2259 2473 2345 2527 2359 1999 2069 2150 2142 1397 1886 2178 1058 1449 1599 987 748 626 654 227 226 196 185 173 142 143 173 101 119 125 <	67.5 70.0 72.5 75.0 1653 1653 1653 1861 1956 1952 1957 1938 2009 1988 1981 1950 2063 2054 2041 2009 2479 2461 2446 2390 2925 2964 2983 2931 3276 3360 3377 3276 3389 3330 3324 3294 3484 3432 3371 3282 3532 3378 3336 2931 3365 2785 2470 2455 2497 2282 2232 2342 2533 2347 2260 2206 2372 2347 2160 1902 2194 1982 1969 1801 1456 1677 1897 1783 1278 1599 2154 1902 1772 2132 2494 2497 2259 2473 2345 2449 2527 2359	1653 1653 1653 1653 1861 1867 1956 1952 1957 1938 1932 2009 1988 1981 1950 1920 2063 2054 2041 2009 1986 2479 2461 2446 2390 2348 2925 2964 2983 2931 2866 3276 3360 3377 3276 3175 3389 3330 3324 3294 3228 3484 3432 3371 3282 3098 3532 3378 3336 2931 2551 3365 2785 2470 2455 2384 2497 2282 2232 2342 2384 2533 2347 2261 2206 2146 2372 2347 2160 1902 1801 2194 1982 1969 1801 1641 1456 1677 1897 1783 1516 1278 1599 2154 1902 1670	67.5 70.0 72.5 75.0 77.5 80.0 1653 1653 1653 1653 1653 1653 1653 1867 1859 1956 1952 1957 1938 1932 1912 2009 1988 1981 1950 1920 1888 2063 2054 2041 2009 1986 1941 2479 2461 2446 2390 2348 2282 2925 2964 2983 2931 2866 2776 3276 3360 3377 3276 3175 3023 3389 3330 3324 3294 3228 3076 3484 3432 3371 3282 3098 2882 3532 3378 3336 2931 2551 2312 3365 2785 2470 2455 2384 2335 2497 2282 2232 2342 2342 2342 2344 2247 2533 2347 2261 2206 2146 1864 2372 2347 2160 1902 1801 1500 1500 1477 1501 1400 <	165.3 165.3 165.3 165.3 165.3 165.3 165.3 165.3 165.3 165.3 165.3 186.3 195.2 190.2 188.8 186.1 190.2 180.3 190.2 180.3 190.2 180.3 190.3 180.3 194.1 190.8 244.9 228.2 224.2 224.2 224.2 224.2 224.2 224.2 224.2 224.2 229.2 224.2 229.2 229.3 237.7 327.6 317.5 30.23 290.7 338.9 333.3 3324.3 329.1 225.5 238.2 <t< td=""><td>67.5 70.0 72.5 75.0 77.5 80.0 82.5 85.0 1653 1653 1653 1653 1653 1653 1653 1653 1859 1861 1866 1956 1952 1957 1938 1932 1912 1908 1890 2009 1988 1981 1950 1920 1888 1861 1836 2063 2054 2041 2009 1986 1941 1908 1884 2479 2461 2446 2390 2348 2282 2224 2168 2925 2964 2983 2931 2866 2776 2777 2719 3389 3330 3324 3294 3228 3076 2943 2778 3389 3330 3324 3291 2551 2312 2253 2264 3532 3378 3336 2931 2551 2312 2253 2204 3365</td></t<> <td> 1653</td>	67.5 70.0 72.5 75.0 77.5 80.0 82.5 85.0 1653 1653 1653 1653 1653 1653 1653 1653 1859 1861 1866 1956 1952 1957 1938 1932 1912 1908 1890 2009 1988 1981 1950 1920 1888 1861 1836 2063 2054 2041 2009 1986 1941 1908 1884 2479 2461 2446 2390 2348 2282 2224 2168 2925 2964 2983 2931 2866 2776 2777 2719 3389 3330 3324 3294 3228 3076 2943 2778 3389 3330 3324 3291 2551 2312 2253 2264 3532 3378 3336 2931 2551 2312 2253 2204 3365	1653

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3458

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(OPPOSITE TO BEAM) CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	1653	1653	1653	1653	1653	1653	1653	1653	1653	1653
2.5	1812	1768	1716	1711	1746	1783	1819	1830	1829	1830
5.0	1880	1814	1808	1875	1886	1948	1974	1961	1952	1955
7.5	1965	1907	1945	1968	2126	2166	2152	2109	2057	2032
10.0	2630	2670	2697	2669	2581	2338	2158	2139	2098	2079
12.5	2902	3046	3116	3352	3317	2857	2497	2530	2509	2494
15.0	2954	3202	3202	3645	3761	3560	3121	2932	2849	2879
17.5	2851	3173	3220	3820	4001	4044	3912	3596	3382	3241
20.0	2516	2849	3093	3650	3650	4121	4109	4052	3687	3495
22.5	2266	2497	2927	3674	3878	3937	3805	3614	3558	3531
25.0	2124	2346	2910	3826	4164	4457	3722	3667	3728	3697
27.5	2050	2196	3065	3919	4585	4847	4222	3910	3734	3691
30.0	2016	2156	2927	4042	4900	5118	3978	3786	3423	2909
32.5	1937	2184	2766	3814	4883	4918	4061	3448	2907	2660
35.0	1687	2196	2835	3417	4573	4416	3847	2802	2374	2423
37.5	1533	2213	2944	3300	4410	4044	3228	2198	1981	2014
40.0	1477	2231	2852	3224	4199	3341	2259	2085	1776	1593
42.5	1471	2283	2852	3312	3948	3081	1908	2014	1606	1327
45.0	1420	2173	2657	3434	3785	2940	1546	1712	1735	1659
47.5	1363	1820	2227	3212	3557	2320	1670	1730	1911	2044
50.0	1335	1537	1991	2938	3084	2095	1891	1528	1653	2085
52.5	1119	1248	1693	2564	2412	2172	1819	1297	1383	1753
55.0 57.5	670	849	1572 1073	2248	1828	2172	1546 1302	1303 1268	1324	1279 983
60.0	335 238	421 277	568	1793 1092	1588 1425	1570 1363	1248	1273	1242 955	942
62.5	170	190	338	800	736	1139	844	1137	873	918
65.0	102	115	166	327	479	543	612	462	861	628
67.5	39	46	45	99	473	88	547	177	287	177
70.0	34	34	34	35	46	64	65	94	117	124
72.5	39	40	40	29	29	29	65	59	52	59
75.0	39	28	57	52	23	17	3.5	41	17	53
77.5	22	17	45	46	23	17	17	$\bar{1}\bar{1}$	17	35
80.0	34	28	80	58	23	17	īi	23	23	17
82.5	85	92	143	81	17	17	17	17	17	17
85.0	113	127	166	87	17	23	29	11	11	17
87.5	119	132	172	81	23	35	35	17	17	17
90.0	125	138	195	64	29	35	35	17	17	11

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(OPPOSITE TO BEAM)

				HO	RIZONTAL	ANGLE				
	95.0	105.0	115.0	125.0	135.0	145.0	155.0	165.0	175.0	180.0
VERT.										
ANGLE										
0.0	1653	1653	1653	1653	1653	1653	1653	1653	1653	1653
2.5	1852	1791	1701	1575	1433	1281	1185	1117	1122	1129
5.0	1810	1610	1387	1168	965	754	467	291	238	237
7.5	1707	1435	1164	724	266	143	131	130	149	160
10.0	1689	1315	736	221	160	137	131	142	143	142
12.5	1828	1152	368	191	142	95	95	89	77	71
15.0	2256	1411	428	287	154	89	65	59	41	41
17.5	2208	1194	537	401	136	65	53	41	35	35
20.0	1737	838	693	503	65	47	41	29	29	29
22.5	1635	760	730	257	53	41	41	41	29	29
25.0	1550	736	675	53	35	53	53	41	35	29
27.5	989	482	132	3.5	23	47	47	35	29	23
30.0	597	386	60	18	23	29	47	29	17	11
32.5	458	265	30	24	23	18	24	23	23	29
35.0	404	193	30	18	23	18	35	29	17	11
37.5	223	132	30	24	23	24	29	11	6	5
40.0	162	78	18	12	5	12	6	5	0	0
42.5	120	60	18	12	5	6	- 6	3	6	5
45.0	84	12	6	0	0	0	0	0	0	0
47.5	66	12	12	3	0	0	0	0	0	0
50.0	36	12	6	6	0	0	0	0	0	0
52.5	24	6	3	3	0	0	0	0	0	0
55.0	30	0	0	0	0	0	0	0	0	0
57.5	42	0	0	0	0	0	0	0	0	0
60.0	18	0	0	0	0	0	0	0	0	0
62.5	18	0	0	0	0	0	0	0	0	0
65.0	0	0	0	0	0	0	0	0	0	0
67.5	0	0	0	0	0	0	0	0	0	0
70.0	0	0	0	0	0	0	0	0	0	0
72.5	0	0	0	0	0	0	0	0	0	0
75.0	0	0	0	0	0	. 0	0	0	0	0
77.5	0	0	0	0	0	0	0	0	0	0.
80.0	0.	0	0	0	· C	0	0	0	0	0 .
82.5	0	0	0	0	0	0	0	-	0	0
85.0	0	0	0	0	0 0	0 0	0	0	0	0
87.5	0	0	0	0 0	. 0	0	0	0	0	0
90.0	0	0	0	U	U	U	U	U	U	U

ENVIRONMENTAL RESEARCH LABORATORIES

7410 E HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK, SCOTTSDALE, ARIZONA 85260 TELEPHONE: (602) 948-3471

CERTIFIED TEST REPORT NO. ERL 3470

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE
SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

REPORT PREPARED FOR:

OCLI, INC. SANTA ROSA, CALIF. CERTIFIED BY:

16" - 6.5" - 15.2"

M. ayers

DATE: APR 16, 1979

THE ATTACHED REPORT IS BASED UPON 58 PLANE PHOTOMETRY VERTICAL TEST INCREMENTS ARE 2.5 DEGREES.

TEST DISTANCE EXCEEDS 25 FT.

TESTED IN ACCORDANCE WITH IES RECOMMENDED PROCEDURES

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3470

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE
SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

UTILIZATION TABLE

COEFFICIENT OF UTILIZATION

RATIO 0.5 1.0 1.5 2.0 2.5 3.0 3.5	HOUSE SIDE 0.043 0.045 0.046 0.046 0.046 0.046 0.046	STREET SIDE 0.235 0.399 0.468 0.491 0.498 0.502 0.505	TOTAL 0.278 0.444 0.514 0.537 0.544 0.548
4.0 5.0	0.046 0.046	0.506 0.507	0.552 0.553
TOTAL:	.46	0.512	0.558
PERCENT:	4.6	51.2	55.8

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3470

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(BEAM SIDE) CANDLEPOWER TABULATION

				1						
	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	1450	1450	1450	1450	1450	1450	1450	1450	1450	1450
2.5	1514	1514	1531	1572	1601	1606	1615	1604	1598	1597
5.0	1543	1555	1618	1653	1653	1653	1668	1669	1670	1662
7.5	1648	1677	1705	1751	1780	1856	1845	1799	1783	1762
10.0	2108	2079	2134	2117	2012	1931	1921	1923	1919	1909
12.5	2405	2347	2476	2534	2436	2262	2257	2290	2306	2316
15.0	2428	2382	2581	2755	2871	2790	2705	2586	2561	2552
17.5	2294	2329	2558	2888	3010	3184	3177	2959	2787	
20.0	2184	2218	2482	2853	3109	3335	3466	3279	3019	2906
22.5	2096	2096	2355	2807	3109	3480	3554	3261	3078	2912
25.0	2003	1985	2285	2807	3312	3735	3719	3083	3090	2894
27.5	1916	1881	2099	2656	3254	3462	3419	3279	3054	2729
30.0	1747	1904	2070	2471	2853	3056		3160	2858	2664
32.5	1654	1945	2065	2389	2737	2900	3130	3077	2864	2487
35.0	1555	1945	2024	2239	2790	2761	2764	2681	2668	2517
37.5	1508	1951	1972	2181	2633	3022	2758	2876	2888	2794
40.0	1485	1945	1960	2111	2703	2952	3041	3119	3102	2971
42.5	1520	1968	1966	2169	2778	2964	3371	3290	3197	3059
45.0	1456	1892	1943	2128	2784	2900	3289	3202	3256	3360
47.5	1316	1642	1867	2146	2685	3033	3024	3261	3482	3601
50.0	1129	1333	1577	2012	2575	2946	3136	3533	3667	3654
52.5	908	1065	1281	1676	2575	2645		3557	3773	
55.0	559	681	933	1438	2500	2424	3489	3876	4035	4091
57.5	285	332	603	991	1902	2204		4238	4261	4179
60.0	227	256	516	759	1189	2018	3501	4143	4190	3872
62.5	168	192	307	719	986	2134	3053	3509	3916	3985
65.0	104	122	185		696	2065	2982	3841	4267	4633
67.5	40	46	75	371	678	2012	2847	4036	4255	4238
70.0	40	40	46	179	649	1688	2776	3433	4053	4085
72.5	34	46	46	69	446	1189	2823	2995	3286	3831
75.0	34	40	46	58	371	1020	2287	2598	2751	2982
77.5	17	23	34	52	324	754	819	1580	1884	2192
80.0 82.5	34 52	34	52	58	295	150	288	538	606	972
82.5 85.0		69	69	46	92	127	165	201	273	341
87.5	87 99	99	92	52	81	139	153	148	255	383
90.0	99 99	110	104	52 46	75 60	127	147	142	261	324
30.0	33	110	104	46	69	110	129	106	71	100

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(BEAM SIDE)

			HOR	HORIZONTAL						
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT. ANGLE										
0.0	1450	1450	1450	1450	1450	1450	1450	1450	1450	3 4 5 0
2.5	1598	1592	1604	1602	1597	1586	1575	1581	1580	1450 1569
5.0	1663	1658	1645	1638	1621	1604	1593	1575	1563	1545
7.5	1740	1717	1692	1667	1644	1615	1605	1575	1569	1545
10.0	1911	1901	1882	1843	1815	1781	1736	1706	1664	1629
12.5	2302	2282	2255	2213	2169	2119	2064	2023	1967	1903
15.0	2551	2531	2503	2442	2369	2278	2231	2220	2193	2142
17.5	2728	2733	2616	2518	2499	2474	2410	2363	2288	2214
20.0	2882	2817	2787	2718	2652	2568	2488	2405	2311	2243
22.5	2746	2615	2486	2436	2434	2332	2172	2088	2020	1933
25.0	2746	2621	2355	2254	2263	2267	2261	2249	2234	2178
27.5	2503	2389	2355	2289	2299	2320	2333	2297	2222	2154
30.0	2539	2436	2426	2342	2210	2101	2035	1993	1949	1885
32.5	2267	2157	2136	2137	2075	2053	2100	2136	2092	2011
35.0	2243	2175	2261	2313	2287	2272	2261	2267	2252	2225
37.5	2657	2490	2616	2712	2770	2752	2751	2703	2615	2524
40.0	2817	2739	2651	2800	2788	2693	2733	2780	2698	2578
42.5	3036	2935	2835	2765	2741	2616	2655	2757	2769	2739
45.0	3261	3197	3077	2688	2770	2841	2977	3168	3161	3103
47.5	3468	3435	3231	2900	2947	2947	3162	3335	3203	3031
50.0	3521	3565	3498	3217	3277	3356	3825	3890	3851	3694
52.5	3924	3815	3723	3428	3607	3853	3956	4093	4291	3992
55.0	4155	4065	3971	4109	4456	4415	4290	4153	4201	3658
57.5	3841	3851	4001	4098	4545	4741	4386	4165	3928	3562
60.0	3592	3732	4042	4004	4256	4356	3896	3604	3482	3097
62.5	3894	4011	4545	4638	4609	5060	4493	3968	3976	3568
65.0	4812	5039	5303	5524	5299	5179	4905	4553	4350	4225
67.5	4829	5271	5865	5976	5800	5534	5078	4475	4249	4058
70.0	4131	5028	5705	5900	6024	5776	4929	4087	3619	3288
72.5 75.0	3989 3433	4088	4699	5013	4916	4451	4022	3479	3304	3133
77.5		3875	4249	4520	4309	4214	3890	3526	3613	3216
80.0	2302 1260	2442	2764	2553	2452	2557	2709	2255	1842	1820
82.5	479	1384 671	1462	1450	1385	1663	1605	1271	1123	960
85.0	420	439	911	1045	1090	1130	931	865	689	572
87.5	343	433	591	593	619	799	925	632	332	411
90.0	130	130	657 272	845 317	807 524	1035 704	1038 561	919	986	638 674
20.0	730	730	412	211	224	/ U 4	201	734	885	0/4

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(BEAM SIDE)

				нс	RIZONTAI	L ANGL	E			
	95.0	105.0	115.0	125.0	135.0	145.0	155.0	165.0	175.0	180.0
VERT. ANGLE										
0.0	1450	1450	1450	1450	1450	1450	1450	1450	1450	1450
2.5	1557	1503	1414	1329	1239	1137	1036		960	974
5.0	1509	1342	1155	986	788	601	461		286	285
7.5	1480	1211	920	583	294	168	137		119	112
10.0	1503	1110	649	240	174	138	119		101	101
12.5	1694	1056	367	192	144	102			77	77
15.0	1832	1062	288	210	138	96	71	53	53	53
17.5	1927	883	355	210	144	54	41		35	35
20.0	1945	853	475	246	66	48	30		29	29
22.5	1653	775	499	228	54	36	24		23	23
25.0	1772	793	379	234	42	24	24		23	23
27.5	1760	781	379	252	42	24	24		17	17
30.0	1402	632	391	270	30	30	24		11	11
32.5	1521	620	391	294	42	42	18		17	17
35.0	1808	823	409	300	48	36	24		17	17
37.5	2088	722	421	324	48	24	18		6	5
40.0	2166	716	445	349	42	18	12		6	5 5 0
42.5	2196	650	451	361	24	18	12		3	5
45.0	2249	477	385	379	18	6	6		0	
47.5	2011	292	270	337	18	6	6		0	3; X + 3
50.0	1796	161	138	228	18	12 12	0	6	0	2
52.5 55.0	1700	113	60	108 36	18	12	6		0	0
57.5	1647 1682	101 95	48	30	18 24	12	12 12	. 12	0	0
60.0	1521	77	30	18	12	6	0		Ö	0
62.5	1306	59	30	18	12	6	ő		ŏ	ŏ
65.0	1187	47	30	18	6	Ö	0	-	0	o.
67.5	1110	41	18	12	12	, š	0		0	ŏ
70.0	907	41	24	12	12	6	ŏ		ŏ	ŏ
72.5	376	29	18	12	6	6	3		0	Ö
75.0	161	29	24	12	6	6	. 6	ō	0	0
77.5	95	6	6	15	9	ő	6		ŏ	ŏ
80.0	83	29	30	18	12	6	6		0	Ō
82.5	71	29	36	36	6	6	6		0	0
85.0	47	35	42	192	36	0	Ō	0	0	0
87.5	53	83	162	210	36	6	6	3	. 0	0
90.0	47	137	330	156	18	. 0	12	: 6	0	0:

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3470

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(OPPOSITE TO BEAM) CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502
2.5	1585	1608	1684	1778	1836	1864	1870	1861	1858	1858
5.0	1602	1661	1849	1901	1889	1905	1893	1879	1882	1876
7.5	1715	1808	2014	1995	2089	2104	2051	1991	1959	1923 ·
10.0	2188	2409	2645	2617	2499	2215	2098	2056	2042	2024
12.5	2507	2821	3110	3209	3063	2607	2361	2368	2387	2392
15.0	2531	2898	3169	3380	3462	3232	2858	2692	2689	2725
17.5	2389	2768	3104	3397	3503	3659	3361	3140	3052	3016
20.0	2277	2645	2945	3256	3356	3706	3647	3446	3218	3040
22.5	2182	2474	2757	3274	3462	3741	3635	3387	3242	3075
25.0	2093	2327	2657	3456	3808	3945	3618	3340	3277	3218
27.5	1987	2185	2527	3438	3943	4290	3770	3411	3289	3069
30.0	1827	2115	2433	3391	4054	4360	3805	3405	3087	2588
32.5	1715	2056	2415	3180	4025	4027	3647	3098	2701	2416
35.0	1626	2061	2444	3063	3802	3542	3250	2468	2333	2274
37.5	1567	2085	2492	3039	3632	3250	2548	2061	2054	2078
40.0	1537	2073	2539	2887	3503	3022	1934	1950	1906	1692
42.5	1585	2073	2627	2863	3421	2940	1642	1761	1585	1223
45.0	1502	1914	2515	3028	3245	2402	1455	1319	1146	1074
47.5	1372	1667	2138	2916	3075	1952	1356	1084	1146	1413
50.0	1177	1343	1820	2552	2775	1636	1613	1254	1252	1330
52.5 55.0	940 585	1072 677	1525 1225	2071 1760	2235 1742	1566 1771	1578 1385	1225 1201	1205 1205	1282 1193
57.5	289	329	771	1390	1414	1449	1221	1184	1175	961
60.0	230	259	500	839	1115	1157	1169	1131	973	849
62.5	177	182	282	669	510	999	835	989	789	813
65.0	106	111	165	340	363	455	555	465	730	659
67.5	47	47	53	88	363	99	467	159	285	195
70.0	41	41	41	41	46	76	81	111	136	112
72.5	35	35	35	29	29	.29	58	53	35	53
75.0	35	35	41	41	23	23	29	29	29	59
77.5	23	23	29	52	23	īī	11	5	5	23
80.0	35	35	47	64	29	23	23	23	17	17
82.5	59	64	94	82	23	23	23	23	23	īi
85.0	88	111	123	88	17	23	17	17	17	17
87.5	106	129	141	76	23	23	23	17	17	17
90.0	100	129	153	70	23	23	23	5	11	5

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(OPPOSITE TO BEAM) CANDLEPOWER TABULATION CONTINUED

				HOR	IZONTAL	ANGLE				
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT.										
ANGLE	1502	1502	1502	1502	1502	1502	3500	1502	3 5 0 2	3 5 0 0
0.0 2.5	1846	1851	1848	1847	1851	1858	1502 1844	1836	1502 1830	1502 1814
5.0	1870	1869	1860	1858	1845	1835	1820	1812	1800	1767
7.5	1900	1863	1836	1823	1810	1800	1785	1758	1746	1714
10.0	2007	1987	1960	1929	1898	1882	1849	1806	1782	1732
12.5	2387	2371	2341	2314	2270	2232	2179	2104	2068	2008
15.0	2749	2756	2769	2759	2690	2607	2492	2360	2289	2203
17.5	2974	2904	2857	2788	2701	2618	2527	2402	2324	2226
20.0	2927	2850	2828	2835	2789	2759	2721	2611	2468	2285
22.5	2921	2856	2898	2916	2853	2729	2527	2277	2193	2097
25.0	3176	3051	2904	2659	2387	2285	2221	2158	2110	2003
27.5	2820	2424	2147	2151	2136	2121	2079	1812	1597	1349
30.0	2226	2064	2018	2051	2113	1917	1655	1305	1186	1060
32.5	2238	2052	1960	1806	1676	1502	1307	1055	935	789
35.0	2161	2010	1666	1385	1246	1180	1131	947	703	524
37.5	2066	1632	1326	1163	1129	1116	977	602	530	471
40.0	1442	1318	1367	1262	1048	824	801	637	530	365
42.5	1062	1236	1390	1186	1007	958	995	780.	554	382
45.0	1205	1531	1654	1706	1519	1438	1337	989	560	223
47.5	1603	1904	1836	1724	1694	1578	1337	500	250	165
50.0	1704	1869	1748	1794	1816	1245	606	274	220	141
52.5	1508	1585	1672	1660	1211 611	537	300	202	155	70
55.0 57.5	1092 956	1455	1725 1079	1303 748	291	321	223	143	95	53
60.0	878	1035 674	416	748 280	238	233 152	153 88	89 113	71 95	41
62.5	682	254	240	228	163	111	111	95	95 95	70
65.0	279	201	217	187	128	134	123	113	83	53
67.5	148	207	181	140	157	128	117	95	53	17
70.0	106	118	105	157	139	122	123	77	5 9	29
72.5	71	59	117	122	104	122	94	113	59	17
75.0	53	112	117	111	145	105	88	35	23	
77.5	35	23	29	52	40	40	23	6	6	- 8
80.0	17	11	41	40	46	35	17	17	11	11 8 5 2 0 0
82.5	11	11	11	11	17	11	17	6	6	2
85.0	11	5	11	11	17	17	17	0	0	0
87.5	11	5 5 5	1 7 5	23 5	17 5	17	5		Ö	0
90.0	5	5	5	5	5	0 -	0	0	0	0

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 100 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 9500 LUMENS

(OPPOSITE TO BEAM)

CANDLEPOWER TABULATION CONTINUED

HORIZONTAL ANGLE 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0 175.0 180.0 VERT. ANGLE 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5 40.0 42.5 б 45.0 O 47.5 50.0 52.5 55.0 57.5 60.0 62.5 _0 65.0 O 67.5 70.0 72.5 75.0 n Ô 77.5 80.0 Ű 82.5 O 85.0 n n n 87.5 O

90.0

ENVIRONMENTAL RESEARCH LABORATORIES

7410 E HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK, SCOTTSDALE, ARIZONA 85260 TELEPHONE: (602) 948-3471

CERTIFIED TEST REPORT NO. ERL 3437

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE

COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

REPORT PREPARED FOR:

OCLI, INC. SANTA ROSA, CALIF.

CERTIFIED BY:

16" -6.5" - 15.2"

DATE: APR 18, 1979

THE ATTACHED REPORT IS BASED UPON 58 PLANE PHOTOMETRY VERTICAL TEST INCREMENTS ARE 2.5 DEGREES.

TEST DISTANCE EXCEEDS 25 FT.

TESTED IN ACCORDANCE WITH IES RECOMMENDED PROCEDURES

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3437

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

UTILIZATION TABLE

COEFFICIENT OF UTILIZATION

RATIO	HOUSE SIDE	STREET SIDE	TOTAL
0.5	0.043	0.285	0.328
1.0	0.045	0.480	0.525
1.5	0.045	0.560	0.605
2.0	0.046	0.582	0.628
2.5	0.046	0.590	0.636
3.0	0.046	0.592	0.638
3.5	0.046	0.594	0.640
4.0	0.046	0.595	0.641
5.0	0.046	0.597	0.643
TOTAL:	0.047	0.602	0.649
PERCENT:	4.7	60.2	64.9

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3437

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(BEAM SIDE)

CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	1211	1211	1211	1211	1211	1211	1211	1211	1211	1211
2.5	1388	1390	1403	1395	1354	1283	1194	1160	1148	1132
5.0	1418	1409	1368	1218	1057	1024	1040	1042	1039	1029
7.5	1463	1446	1352	1084	1113	1148	1207	1206	1186	1159
10.0	1799	1806	1568	1302	1305	1390	1247	1199	1184	1175
12.5	1920	1928	1708	1836	1733	1488	1601	1623	1641	1630
15.0	2002	1998	1716	1769	1991	2097	1836	1820	1858	1851
17.5	2069	2124	1823	1928	1972	2169	2323	2027	1864	1819
20.0	1738	1865	1756	2000	2076	2205	2261	2012	2149	2019
22.5	1538	1741	1711	1904	2325	2386	2344	2097	1961	1897
25.0	1478	1699	1771	2030	2694	2706		2125	2123	1903
27.5	1386	1514	1473	1800	2577	2729	2708	2276	1956	1899
30.0	1536	1492	1397	1646	2214	2429	2660	2429	2355	2142
32.5	1427	1431	1458	1589	1879	1956	2541	2425	2318	1857
35.0	1459	1356	1409	1504	1855	1839	2029	1970	1957	1793
37.5	1050	1284	1239	1570	1844	2203	1938	2000	1995	1763
40.0	980	1220	1161	1437	1983	2325	1961	2103	2323	2331
42.5	960	1291	1160	1457	1826	2237	2208	2371	2423	2307
45.0 47.5	992	1286	1202	1464	1941	2158	2415	2148	2338	2201
	926 843	1175 915	1230	1454 1517	1925 1739	2000	2214	2084	2464	2801
50.0 52.5	603	860	1115 978	1105		1882 1384		2746	2819	2909 3732
55.0	277	396	697	1074		1384	2348	2899 3630	3916 4209	4068
57.5	153	203	357	664	1419	1267	2764 2965	3526	3792	3487
60.0	94	129	275	592	649	1414	2309	3440	3506	3177
62.5	52	64	160	453			2234	2543		3411
65.0	40	42	68	422	548	1224	2426	2693	3259	3649
67.5	29	31	42	248	401	1365	1726	2928	3310	3253
70.0	28	29	34	64	455	1216	1882	2303	3004	2859
72.5	25	26	34	43	349		1737	1494	1888	2170
75.0	31	29	32	38	283	666	906	1197	1487	2013
77.5	22	23	24	39	256	288		967	1271	1411
80.0	25	32	30	40	48	77	166	175	225	552
82.5	58	61	61	42	50	113	130	86	150	144
85.0	86	81	78	42	55	103	128	61	133	177
87.5	89	77	78	36	45	76	116	75	95	170
90.0	92	77	81	36	52	91	104	62	35	42

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(BEAM SIDE)

				HOR	IZONTAL	ANGLE				
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT.										
0.0	1211	1211	1211	1211	1211	1211	1211	1211	1211	1211
2.5	1125	1272	1107	1093	1084	1078	1076	1074	1076	1080
5.0	1023	1159	1009	1003	999	992	989	975	967	966
7.5	1145	1289	1108	1089	1071	1046	1031	1008	981	969
10.0	1178	1337	1157	1135	1103	1069	1040	1006	972	944
12.5	1623	1827	1573	1536	1493	1453	1409	1362	1317	1273
15.0	1799	1928	1599	1557	1558	1537	1470	1314	1196	1146
17.5	1734	1902	1759	1782	1762	1722	1668	1587	1525	1479
20.0	1844	2054	1801	1806	1781	1757	1757	1704	1620	1484
22.5	1874	1948	1724	1641	1453	1441	1510	1519	1472	1428
25.0	1586	1744	1596	1557	1582	1615	1614	1594	1552	1485
27.5	1743	1933	1772	1798	1824	1802	1726	1579	1527	1473
30.0	1972	2118	1725	1637	1481	1464	1435	1278	1178	1107
32.5	1714	1831	1521	1541	1524	1441	1447	1342	1250	1200
35.0	1653	1872	1536	1492	1515	1466	1568	1545	1517	1504
37.5	1752	1968	1857	1871	1963	1952	1916	1792	1703	1706
40.0	2187	2256	1996	2063	1986	1856	1911	1802	1638	1600
42.5	2109	2460	2244	1969	2018	1941	1910	1853	1731	1732
45.0	2193	2680	2502	2382	2294	2318	2132	2162	2101	2058
47.5	2861	2780	2272	2331	2439	2318	2392	2339	2302	2248
50.0	2650	3053	2730	2566	2875	3103	3096	2976	2956	2713
52.5	3441	3623	3324	3163	3175	3303	3320	3518	3284	2838
55.0	3630	3318	2886	3306	3223	3102	3042	3242	3387	2753
57.5	3309	3657	2831	3019	3342	3148	3117	3408	3126	2407
60.0	3025	3602	3052	3247	3564	3548	3334	3061	2870	2297
62.5	3392	3469	4222	4127	3895	4289	3746	4104	3343	3131
65.0	3593	4303	3571	4022	3796	4074	3645	3392	3035	2721
67.5	3384	3649	3918	4354	4099	4369	4146	3442	2930	2514
70.0	2649	2974	3369	3580	3564	3891	3371	3086	2500	1998
72.5	2495	2970	2997	3665	3543	3561	3080	2721	2442	2206
75.0	2253	3040	2983	3644	2923	3072	2813	2490	2068	1725
77.5	1392	1671	1904	2008	1939	2001	2158	1600	1407	1364
80.0	740	980	967	949	979	990	940	795	540	447
82.5	189	323	322	325	354	420	510	550	274	287
85.0	176	260	269	351	313	326	576	511	380	343
87.5	160	250	296	449	461	614	651	664	662	472
90.0	65	79	79	57	71	82	95	109	90	65

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(BEAM SIDE)

				ноі	RIZONTAL	ANGLE				
	95.0	105.0	115.0	125.0	135.0	145.0	155.0	165.0	175.0	180.0
VERT.										
ANGLE				2.242.274						
0.0	1211	1211	1211	1211	1211	1211	1211	1211	1211	1211
2.5	1077	1079	1083	1062	1061	1044	987	880	787	755
5.0	951	910	784	636	525	397	296	208	135	122
7.5	941	758	466	192	116	93	92	107	130	130
10.0	901	593	264	98	79	72	74	79	116	125
12.5	1160	584	138	92	77	61	57	50	44	44
15.0	1103	527	119	90	63	52	33	31	29	29
17.5	1270	444	138	89	63	31	23	22	20	20
20.0	1224	545	245	103	36	29	17	16	14	15
22.5	1244	577	303	103	27	22	14	14	14	14
25.0	1227	602	184	126	24	16	15	17	14	14
27.5	1198	576	201	135	19	22	16		15	16
30.0	836	287	231	160	17	31	26	16	9	13
32.5	879	326	216	194	25	29	17	11	15	16
35.0	1102	427	237	179	49	27	28	16	7	5
37.5	1414	376	249	196	49	14	9	6	4	4
40.0	1433	405	265	219	33	7.	7		1	1
42.5	1458	282	274	233	18	10	2	14	2	2
45.0	1259	134	178	241	14	3	2		0	0
47.5	1009	62	48	179	11	5	1	7	- 0	0
50.0	1066	54	28	58	7	9	0	6	0	0
52.5	1174	56	25	32	8	8	2 3 2 2	3 2	0	0
55.0	1099	46	22	25	11	. 7	3	2	0	0
57.5	1211	40	20	10	8:	5	2	0	0	0
60.0	1058	33	19	9	9	3	2	. 0	0	0
62.5	839	30	18	11	8	3 2	3	0	0	0
65.0	750	24	20	7	8		0	0	0	0
67.5	625	21	18	9	10	3	2	1	0	0
70.0	167	18	21	10	8	3	3	0	0	0
72.5	82	17	16	10	6	: 3	2	0	0	0
75.0	94	14	14	11	9	2	2	0	0	0
77.5	51	11	11	10	- 7	-3	3	2	0	0
80.0	37	14	15	19	7	2 2	2 2 3 2 2	0	0	0
82.5	29	15	19	89	22		2	0	0	.0
85.0	21	29	64	76	21	1	2	1	0	0
87.5	102	55	161	133	5	0	2 3 7	1	0	0
90.0	53	123	278	113	13	- 0	7	5	0	0

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3437

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(OPPOSITE TO BEAM)

CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
W 47 20% NPA 100'S										
VERT.										
ANGLE 0.0	1168	1168	1168	1168	1168	1168	1168	1168	1168	1168
2.5	1339	1327	1327	1356	1386	1403	1409	1406	1401	1393
5.0	1368	1371	1384	1387	1380	1380	1379	1375	1374	1369
7.5	1411	1410	1433	1456	1457	1451	1449	1440	1431	1419
10.0	1736	1760	1823	1770	1601	1467	1340	1326	1334	1328
12.5	1852	1936	2078	2362	2245	1688	1457	1487	1509	1513
15.0	1931	2083	2079	2375	2462	2372	1895	1836	1849	1861
17.5	1996	2207	2135	2512	2640	2642	2588	2271	2143	2105
20.0	1677	1883	2023	2475	2394	2465	2558	2620	2471	2256
22.5	1483	1739	1887	2416	2533	2617	2672	2586	2639	2477
25.0	1426	1640	2019	2522	2918	3122	2739	2719	2712	2601
27.5	1337	1371	1995	2584	3086	3364	3088	2675	2574	2591
30.0	1481	1367	1774	2615	3153	3612	3057	2758	2385	2068
32.5	1376	1401	1717	2357	2915	3535	3054	2679	2204	1741
35.0	1098	1352	1759	2187	2618	2984	2856	2305	1814	1625
37.5	1013	1345	1760	2052	2693	2788	2635	1623	1415	1456
40.0	945	1338	1702	1880	2596	2275	1702	1320	1184	1299
42.5	926	1405	1711	1860	2408	2153	1287	1374	1375	1239
45.0	957	1412	1616	1852	2398	2086	1320	1390	1295	1134
47.5	894	1159	1291	1780	2313	2085	1304	1088	921	1054
50.0	813	896	1101	1727	2148	1896	1188	653	660	1013
52.5 55.0	582	705	918	1511	1707	1713	1035	473	522	625
57.5	267 148	315 164	764 518	1442 1007	1374 1230	1326 829	757	472	489 524	536
60.0	91	94	254	571	770	739	508 558	498 557	468	455 461
62.5	50	52	234 77	458	425	546	351	482	471	518
65.0	39	39	42	168	331	196	361	204	494	320
67.5	28	30	34	37	249	53	318	95	107	93
70.0	27	26	26	24	29	45	47	57	78	77
72.5	24	24	25	19	17	18	40	38	23	20
75.0	30	23	43	36	17	15	19	15	13	28
77.5	21	17	38	32	14	īi	14	11	11	20
80.0	24	22	49	33	14	14	13	14	īż	13
82.5	56	61	83	51	īī	13	14	19	îż	14
85.0	83	90	107	60	16	17	22	16	17	19
87.5	86	89	114	42	18	20	22 22	15	17	12
90.0	89	90	128	33	19	22	22	10	14	9

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(OPPOSITE TO BEAM) CANDLEPOWER TABULATION CONTINUED

				HOR	IZONTAL	ANGLE				
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT.										
ANGLE										
0.0	1168	1168	1168	1168	1168	1168	1168	1168	1168	1168
2.5	1386	1380	1378	1374	1374	1378	1374	1366	1356	1352
5.0	1360	1353	1351	1333	1314	1310	1310	1308	1290	1277
7.5	1409	1400	1388	1367	1335	1319	1294	1286	1253	1232
10.0	1322 1528	1322 1534	1315 1539	1298	1261	1254	1224	1219 1298	1192 1237	1174
12.5	1528	1534	1539	1504	1447	1412	1342	1298	1237	1197
15.0	1917	1945	1958	1925	1838	1791	1724	1730	1720	1698
17.5	2118	2164	2177	2093	1988	1900	1777	1697	1623	1594
20.0	2122	2080	2048	1999	1916	1826	1674	1573	1511	1507
22.5	2309	2190	2155	2126	2086	2031	1912	1645	1306	1212
25.0	2440	2373	2169	2122	1925	1552	1401	1341	1237	1174
27.5	2441	2125	1831	1550	1473	1441	1370	1304	1015	789
30.0	1800	1529	1516	1544	1475	1435	1154	852	670	568
32.5 35.0	1599 1513	1518	1491	1592	1390	1102	891	751	558	428
37.5	1513	1544 1496	1486 1202	1218	1108 995	940 872	777	620	419	373
40.0	1276	1271	1358	1060 1276	1218	910	654 763	443 657	404 570	363 416
42.5	1295	1505	1673	1407	1254	1008	902	644	495	259
45.0	1228	1461	1513	1362	1287	1205	856	537	116	91
47.5	1189	1290	1185	1295	1342	1031	524	153	99	113
50.0	1103	1112	1028	1185	1026	550	182	116	151	130
52.5	948	967	1051	1010	528	201	153	161	133	102
55.0	588	940	1065	651	241	173	162	149	101	86
57.5	487	635	809	207	170	170	157	110	80	62
60.0	511	346	246	187	178	151	131	91	55	32
62.5	244	114	153	138	146	106	94	88	59	47
65.0	120	116	107	124	95	87	86	92	51	47
67.5	81	93	107	82	91	105	126	95	60	44
70.0	66	71	73	72	105	109	87	91	56	26
72.5	36	35	33	92	93	78	104	71	48	34
75.0	33	33.	83	90	79	106	82	67	24	13
77.5	27	30	28	48	50	44	35	33	14	11
80.0	9	10	12	27	26	24	15	9	3	2 1 0
82.5	11	8	6	6	6	6	7	9 6	3	1
85.0	9	6	6	6	6 5 7	3	8 5		1	0
87.5	10	4	6	11		7	5	1	0	0
90.0	9	5	6	3	2	2	1	0	0	0

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE COATED SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(OPPOSITE TO BEAM)

				HOI	RIZONTAL	ANGLE				
	95.0	105.0	115.0	125.0	135.0	145.0	155.0	165.0	175.0	180.0
VERT.										
ANGLE										
0.0	1168	1168	1168	1168	1168	1168	1168	1168	1168	1168
2.5	1339	1319	1281	1196	1082	949	824	739	715	729
5.0	1260	1196	1009	847	680	471	268	141	114	118
7.5	1201	1016	725	431	164	109	98	107	118	125
10.0	1137	828	427	137	111	99	99	115	115	120
12.5	1099	650	228	138	113	83	77	53	44	43
15.0	1566	917	314	234	110	62	39	33	28	28
17.5	1474	783	385	293	93	36	33	25	20	19
20.0	1297	464	429	177	38	31	24	18	14	14
22.5	921	412	420	79	29	20	20	22	14	13
25.0	849	387	383	28	21	24	29	28	14	13
27.5	491	254	65	18	14	30	31	26	15	15
30.0	324	200	22	12	16	15	33	19	13	12
32.5	253	93	17	12	16	10	16	13	16	16
35.0	214	64	14	11	11	. 8	20 17	19	7	5
37.5 40.0	85 70	48 41	14 12	11 8	9	11 13	4	5 2	1	4
42.5	47	30	9	7	6	3	3	ő	0	1
45.0	43	10	7	3	2	0	0	0	0	2
47.5	37	10	. 8	3 4	2	0	ő	0	. 0	0
50.0	23	7	7	3	ő	0	0	0	. 0	. 0
52.5	13		3	1	0	0	0	Ö	0	0
55.0	14	5 3	í	Ö	0	0	o .	ő	ő	0
57.5	30	3	î.	0	ő	0	. 0	0	ő	. 0
60.0	14	2	Ō	ő	ő	0	Ö	ő	0	0
62.5	îi	ī	ŏ	Ŏ.	ő	0	Ö	ő	ŏ	0
65.0	7	Ô	ő	0	ő	0	Ö.	ő	ŏ	ő
67.5	2	ĭ	Ŏ	ŏ	ŏ	ŏ	Ö	ő	ŏ	ő
70.0	3	2	Ŏ	ŏ	ŏ	ő	ŏ	Ŏ.	ŏ	ŏ
72.5	3 2	ī	Ö	ŏ	õ	ŏ	Ö	0	ō	ŏ
75.0	1	0	Õ	Ö	Ō	Ö	Ö	Ô	0	Ŏ
77.5	0	Ō	0	. 0	0	0	Ö	0	0	Ŏ
80.0	0	0	Ö	Ō	0	0	0	0	0	0
82.5	Õ	Ö	ŏ	ő	Ö	ŏ	0	Ö	õ	Ö
85.0	ő	ŏ	ő	ŏ	ő	ŏ	Õ	ō	ŏ	ŏ
87.5	Õ	ŏ	Ö	ŏ	ŏ	ŏ	ŏ	Õ	Ō	ŏ
90.0	0	0	Ō	Ō	Ö	Ō	Ō	Ō	0	Ŏ

ENVIRONMENTAL RESEARCH LABORATORIES

7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK, SCOTTSDALE, ARIZONA 85260 TELEPHONE: (602) 948-3471

CERTIFIED TEST REPORT NO. ERL 3471

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE
SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

REPORT PREPARED FOR:

OCLI, INC. SANTA ROSA, CALIF.

CERTIFIED BY:

16"
-6.5"

18.4"

15.2"

DATE: APR 18, 1979

THE ATTACHED REPORT IS BASED UPON 58 PLANE PHOTOMETRY VERTICAL TEST INCREMENTS ARE 2.5 DEGREES.

TEST DISTANCE EXCEEDS 25 FT.

TESTED IN ACCORDANCE WITH IES RECOMMENDED PROCEDURES

ENVIRONMLATAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3471

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE
SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS
ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

UTILIZATION TABLE

COEFFICIENT OF UTILIZATION

RATIO	HOUSE SIDE	STREET SIDE	TOTAL
0.5	0.040	0.236	0.276
1.0	0.042	0.394	0.436
1.5	0.042	0.459	0.501
2.0	0.042	0.477	0.515
2.5	0.042	0.484	0.526
3.0	0.042	0.487	0.529
3.5	0.042	0.489	0.531
4.0	0.042	0.490	0.532
5.0	0.042	0.490	0.532
TOTAL:	0.043	0.495	0.538
PERCENT:	4.3	49.5	53.8

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3471

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(BEAM SIDE)

CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	865	865	865	865	865	865	865	865	865	865
2.5	941	933	934	964	970	976	972	976	972	964
5.0	1002	993	1009	1015	997	987	998	1006	1005	1002
7.5	1044	1033	1043	999	1034	1092	1108	1098	1086	1061
10.0	1301	1267	1297	1219	1188	1138	1135	1133	1129	1131
12.5	1420	1348	1436	1517	1441	1353	1373	1418	1430	1422
15.0	1439	1380	1484	1579	1716	1762	1564	1537	1571	1568
17.5	1410	1446	1569	1767	1929	1911	1888	1738	1646	1595
20.0	1335	1390	1479	1743	1964	2060	2000	1868	1765	1670
22.5	1304	1317	1436	1633	1907	2174	2080	2014	1894	1719
25.0	1246	1156	1265	1579	2026	2394	2198	2044	1945	1845
27.5	1206	1117	1252	1496	1894	2234	2209	2090	1824	1633
30.0	1063	1109	1281	1504	1649	1906	2075	1860	1921	1676
32.5	970	1112	1265	1466	1676	1529	1759	1938	1778	1476
35.0	899	1072	1158	1359	1662	1681	1780	1759	1678	1492
37.5	838	1057	1078	1305	1563	1868	1780	1914	1886	1748
40.0	791	1022	1017	1294	1576	1854	1944	2044	1983	1854
42.5	785	1001	993	1184	1552	1711	2137	2193	2069	1870
45.0	791	980	1006	1147	1581	1816	2163	2104	2096	2072
47.5	740	872	1006	1179	1552	1797	1872	2212	2247	2247
50.0	582	681	857	1176	1501	1754	1981	2239	2492	2325
52.5	486	610	760	891	1474	1496	1984	2318	2484	2589
55.0	219	299	472	843	1358	1491	2201	2576	2506	2632
57.5	150	199	323	545	1015	1247	2370	2665	2581	2514
60.0	103	134	259	521	765	1174	1955	2467	2468	2366
62.5	6.0	78	149	502	611	1288	1984	2351	2700	2975
65.0	37	3.9	64	346	466	1209	2030	2597	2802	3171
67.5	21	23	34	201	458	1231	1829	2516	2665	2484
70.0	21	23	29	61	439	978	1866	2047	2460	2581
72.5	15	18	24	34	301	732	1711	1735	1727	2277
75.0	18	18	24	29	277	599	814	1138	1576	1959
77.5	15	18	21	26	245	222	235	320	374	765
80.0	21	21	24	34	83	78	141	179	212	344
82.5	23	26	32	32	53	73	93	116	140	215
85.0	42	50	50	32	48	81	88	89	142	172
87.5	55	57	58	32	45	67	93	78	83	115
90.0	60	63	64	32	40	67	88	67	51	113

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(BEAM SIDE)

				HOR	IZONTAL	ANGLE				
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT.										
0.0	865	865	865	865	865	865	865	865	865	865
2.5	968	970	967	970	965	969	950	953	945	944
5.0	1004	995	983	978	970	975	961	948	936	925
7.5	1061	1035	1026	1013	1002	994	972	970	959	936
10.0	1124	1103	1104	1097	1084	1082	1057	1031	1014	987
12.5	1429	1429	1417	1394	1370	1355	1308	1264	1229	1187
15.0	1574	1548	1519	1492	1454	1421	1380	1336	1263	1165
17.5	1596	1551	1589	1632	1603	1578	1523	1477	1426	1375
20.0	1607	1629	1689	1711	1684	1628	1556	1491	1445	1419
22.5	1634	1518	1517	1519	1454	1330	1247	1316	1326	1274
25.0	1675	1385	1344	1462	1438	1394	1402	1400	1359	1318
27.5	1645	1521	1476	1443	1419	1427	1410	1375	1315	1258
30.0	1620	1559	1509	1400	1289	1253	1220	1167	1119	1056
32.5	1389	1342	1317	1297	1294	1314	1344	1303	1260	1211
35.0	1369	1347	1414	1459	1516	1528	1567	1538	1484	1416
37.5	1700	1567	1587	1735	1721	1675	1672	1633	1569	1511
40.0	1844	1724	1678	1757	1732	1677	1675	1663	1597	1560
42.5	1893	1854	1854	1811	1727	1683	1655	1682	1683	1656
45.0	2022	2017	1956	1735	1751	1809	1870	1915	1835	1765
47.5	2213	2115	2088	1762	1757	1851	1975	2018	1906	1730
50.0	2254	2223	2279	2051	2027	2135	2413	2473	2351	2234
52.5	2562	2272	2322	2332	2343	2465	2432	2572	2542	2344
55.0	2794	2429	2277	2695	2689	2603	2564	2506	2456	2123
57.5	2404	2511	2366	2468	2800	2804	2650	2445	2255	2073
60.0	2286	2383	2616	2638	2754	3016	2757	2284	2163	1951
62.5	3059	3140	3287	3297	3068	3261	3209	2800	2755	2614
65.0	3211	3319	3479	3903	3662	3294	3440	2869	2487	2256
67.5	2737	3140	3632	3908	3825	3584	3446	2772	2503	2273
70.0	2592	3148	3446	3662	3600	3471	3225	2656	2161	1967
72.5	2586	2597	2926	3078	3038	2663	2675	2376	2354	2188
75.0	2082	2296	2433	2557	2349	2314	2303	2098	1672	1580
77.5	848	924	1145	1100	1043	1168	1242	928	685	605
80.0	562	683	746	719	783	793	732	590	671	491
82.5	256	284	323	383	394	506	490	415	221	259
85.0	201	227	326	475	489	498	617	562	511	362
87.5	109	127	185	240	356	424	369	335	608	453
90.0	84	124	188	132	194	236	228	363	339	182

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(BEAM SIDE)

				HOE	RIZONTAL	ANGLE				
	95.0	105.0	115.0	125.0	135.0	145.0	155.0	165.0	175.0	180.0
VERT. ANGLE										
0.0	865	865	865	865	865	865	865	865	865	865
2.5	941	922	903	840	748	662	577	520	515	531
5.0	905	867	717	556	417	267	Ĭ73	116	96	97
7.5	903	744	472	212	111	89	75	70	69	7.3
10.0	941	654	316	112	86	77	73	65	67	.67
12.5	1104	596	166	99	72	52	48	46	43	43
15.0	1058	495	161	112	72	50	35	29	26	29
17.5	1262	448	185	126	69	30	24	19	18	19
20.0	1283	459	242	132	36	27	19	16	13	13
22.5	1112	487	281	121	25	16	13	10	10	10
25.0	1137	490	199	137	25	13	13	13	13	10
27.5	1128	490	191	140	19	11	13	10	8	8
30.0	889	331	201	143	19	19	13	8	8	. 8
32.5	1031	350	196	157	22	19	10	10	8	5
35.0	1205	503	210	146	27	19	10	10	8	13
37.5	1335	399	215	148	27	13	8	8	5	5
40.0	1365	391	223	151	25	8	2	2	2	0
42.5	1324	331	229	157	16	8	2	5 5	1	0
45.0	1232	188	171	151	5	2	0	5	0	0
47.5	1128	84	68	118	. 8	5	2	8	0	0
50.0	1150	71	32	52	11	8	2	8	0	0
52.5	1145	60	24	22	13	5 5	2	5 2	1	0
55.0 57.5	1033 1041	54 46	21 21	22	13 11	8	2		2	0
60.0	952	38	16	13 11	11	ວ ວ	· &.	1 0	1 0	0 0
62.5	821	30	16	8	8	2 5	2 2 2 2 2 2	2	0	0
65.0	764	27	16	8	8	2		0	0	0
67.5	688	21	10	5	5	2	2 2	0	Ö	0
70.0	318	19	16	8	8	2	2	Ö	0	0 -
72.5	108	16	13	8		ī	ĩ	ŏ	ŏ	Ö
75.0	8.9	16	13	8.	2	ō	ō	Ō.	Ŏ	ŏ
77.5	51	10	10	5	2 2 2	1	ĭ	i	Ö	
80.0	49	16	16	13	8	. 2		2	Ö	1 2 1
82.5	38	16	19	16	8		2 2 2	2	2	1
85.0	27	21	21	41	13	5 2	2	0	0	0
87.5	27	32	40	99	25	2	2	1	0	0
90.0	92	71	90	115	13	5	5	2	0	0

ENVIRONMENTAL RESEARCH LABORATORIES INC. 7410 E. HELM DRIVE, THUNDERBIRD INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. ERL 3471

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(OPPOSITE TO BEAM) CANDLEPOWER TABULATION

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	60.0	62.5	65.0
VERT.										
ANGLE										
0.0	880	880	880	880	880	880	880	880	880	880
2.5	962	988	1061	1110	1134	1118	1096	1086	1088	1088
5.0	1016	1058	1171	1174	1169	1155	1130	1123	1117	1113
7.5	1060	1107	1242	1222	1223	1206	1180	1169	1163	1153
10.0	1313	1428	1601	1538	1409	1270	1188	1179	1182	1178
12.5	1441	1612	1822	1888	1755	1458	1359	1364	1377	1384
15.0	1460	1655	1887	1921	1976	1915	1597	1527	1549	1546
17.5	1436	1682	1890	1947	2068	1979	1931	1701	1655	1679
20.0	1357	1595	1760	1904	1798	2137	2063	2001	1863	1722
22.5	1321	1468	1671	1859	2046	2121	2008	1982	1968	1817
25.0	1261	1317	1571	1993	2179	2343	2097	1979	2011	1985
27.5	1218	1282	1398	1979	2338	2413	2168	1998	1965	1963
30.0	1076	1188	1366	1888	2281	2472	2255	2102	1895	1646
32.5	981	1142	1350	1824	2141	2317	2184	2014	1703	1497
35.0	912	1144	1355	1688	2041	1939	1963	1610	1514	1400
37.5	850	1128	1401	1581	2011	1805	1541	1244	1233	1310
40.0	798	1112	1436	1450	1887	1672	1056	1113	1088	1107
42.5	798	1115	1441	1401	1836	1613	911	989	980	755
45.0 47.5	809	1047	1377	1500 1500	1803	1557	867	880	810	828
50.0	754	936	1120		1744	1209	1014	877	718	817
52.5	591 493	696 577	950 810	1436 1048	1584 1304	1131 1222	1159	692 671	720	788
55.0	223	280	623	1048	1304	1209	1083 761	658	691 672	771 671
57.5	152	183	348	778	999	920	693	639	631	
60.0	106	118	232	519	607	920 805	653	610	475	503 463
62.5	62	62	232 97	369	369	599	453	489	423	457
65.0	32	37	48	187	318	208	318	262	415	284
67.5	21	24	29	34	261	56	242	99	129	100
70.0	21	ži	18	18	27	45	44	58	67	67
72.5	19	18	18	16	13	16	34	32	18	24
75.0	19	16	21	18	13	10	13	13	10	27
77.5	13	16	18	26	13	10	10	8	10	16
80.0	19	18	24	32	16	10	15	8	13	8
82.5	24	24	43	42	13	13	15	13	16	10
85.0	43	56	70	53	10	13	10	13	10	10
87.5	57	67	81	48	10	13	15	10	10	8
90.0	60	70	89	42	16	13	13	8	13	8

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(OPPOSITE TO BEAM)

				нон	IZONTAL	ANGLE				
	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
VERT. ANGLE										
0.0	880	880	880	880	880	880	880	880	880	880
2.5	1082	1077	1077	1074	1066	1068	1071	1064	1063	1055
⅓ 5.0	1104	1098	1096	1090	1088	1084	1069	1056	1047	1033
7.5	1139	1131	1118	1101	1093	1095	1079	1064	1052	1039
10.0	1163	1150	1142	1114	1107	1092	1074	1061	1049	1033
12.5	1382	1374	1367	1337	1306	1259	1218	1165	1130	1090
15.0	1544	1544	1535	1507	1487	1464	1454	1424	1402	1356
17.5	1706	1736	1746	1706	1693	1674	1608	1523	1475	1421
20.0	1698	1684	1703	1714	1741	1712	1656	1560	1494	1432
22.5	1717	1722	1744	1749	1760	1749	1640	1432	1313	1246
25.0	1887	1792	1801	1738	1530	1391	1366	1325	1270	1224
27.5	1763	1579	1394	1399	1379	1364	1324	1213	1004	759
30.0	1414	1317	1278	1345	1344	1257	1015	778	702	600
32.5	1377	1290	1237	1251	1136	877	808	685	554	425
35.0	1350	1282	1161	829	823	724	659	578	398	298
37.5	1304	1055	807	710	666	664	518	384	314	269
40.0	985	864	842	732	626	489	470	424	344	231
42.5	745	966	1094	934	853	756	741	618	489	258
45.0	966	1185	1156	1090	920	874	744	618	201	91
47.5	990	1136	1110	1076	1012	845	598	178	102	83
50.0	1012 783	1061	1012 929	1060 990	1053	538	196	122	110	91
52.5 55.0		861			704	185	138	117	102	59
57.5	604 531	780 583	961 509	638 263	337 151	158	133 103	98 56	59 45	45
60.0	491	291	149	263 137	129	142 105	61	42	64	35 40
62.5	288	110	127	126	116	75	53	64	45	35
65.0	102	108	102	110	78	59	71	61	43	32
67.5	75	94	111	83	67	72	77	56	40	18
70.0	67	75	70	67	83	70	69	61	35	24
72.5	35	32	35	75	67	64	58	42	51	16
75.0	24	32	62	51	59	59	39	42	18	
77.5	24	18	19	32	24	26	18	iõ	ξ.	2
80.0	8	. 8	16	21	21	18	13	8	5 8	2
82.5	10	. 8	8	8	ĩō	10	10	5	2	8 2 2 2
85.0	8	- 5	8 5	8	8	10	10	5 2	2	õ
87.5	8	2	- 5	10	- 8	8	2	2	ī	Ö
90.0	5	5	5	- 5	5	5	2	0	0	Õ

UPSTREAM DIRECTIONAL FREEWAY LUMINAIRE SPECULAR ALUMINUM REFLECTOR, CLEAR PLASTIC LENS ONE 70 WATT CLEAR HIGH PRESSURE SODIUM LAMP, RATED 5800 LUMENS

(OPPOSITE TO BEAM)

CANDLEPOWER TABULATION CONTINUED

HORIZONTAL ANGLE 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0 175.0 180.0 VERT. ANGLE 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5 40.0 42.5 45.0 Ω Ω 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5 Ω 80.0 82.5 85.0 87.5 n 90.0



LIGHTING SCIENCES INC.

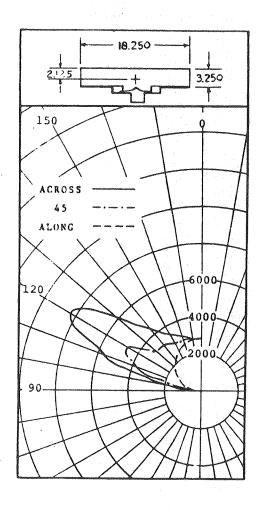
7730 E. Redfield Rd. Scottsdale Arizona 85260 602-991-9260

CERTIFIED TEST REPORT NO. LSI 1069 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE

HIGH REFLECTANCE ALUM. REFLECTOR AND HIGH TRANSMITTANCE COVER GLASS PARRELECTOR ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

+ lews coated.



	CANDI	EPOWE	R SUMM	ΛRY		OUTPUT
ANGLE	ACROSS	67.5	45	22.5	ALONG	
180	2768	2768	2758	2768	2768	
175	2768	2795	2768	2768	2768	265
170	2837	2865	2810	2740	2754	
165	2946	2948	2823	2713	2598	802
160	3070	3031	2851	2599	2528	
155	3275	3169	2879	2643	2558	1346
150	3577	3377	2920	2574	2460	
145	3837	3654	3017	2505	2335	1927
140	4193	3889	3183	2408	2195	
135	4947	4360	3239	2297	2013	2623
130	6084	5328	3252	2228	1817	
125	7564	6657	3737	2201	1650	3846
120	8304	7681	4595	2242	1524	
115	7537	7100	4567	2256	1342	4381
110	5659	5218	3681	2173	1104	
105	4837	4609	3059	1689	811	2968
100	2275	2228	1505	886	433	
95	713	747	540	318	210	695
90	Ø	Ø	0	0)	. 0	

ZONAL LUMENS AND PERCENTAGES

ZONE	LUMENS	& LAMP	% FIXTURE
180-150	2413	9.65	12.80
180-140	4340	17.36	23.02
180-120	10809	43.24	57.33
180-90	18853	75.42	100.00
140-90	14513	58.05	76.98
120-90	8044	32.18	42.67
180-90	Ø	0.00	0.00
0-180	18853	75.42	100.00

** EFFICIENCY = 75.42% **

CERTIFIED BY:

DATE: JUL 06, 1979

PREPARED FOR:

LIGHTING R & D

TESTED IN ACCORDANCE WITH IES PROCEDURES. TEST DISTANCE = 8 METERS (26 FT.)

LIGHTING SCIENCES INC. 7730 E. REDFIELD ROAD, SCOTTSDALE INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. LSI 1069 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE
HIGH REFLECTANCE ALUM. REFLECTOR AND HIGH TRANSMITTANCE COVER GLASS
ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMs.

CANDLEPOWER DATA IN 2.5 DEGREE STEPS

ANG	GLE			PL.	ANE			OUTPUT
		ACROSS	67.5	45	22.5	ALONG	AVERAGE	LUMENS
18	0.0	2768	2768	2768	2768	2768	2768	
17:	7.5	2782	2768	2768	2768	2782	2772	
17	5.0	2768	2796	2768	2768	2768	2775	265
17	2.5	2809	2837	2796	2740	2754	2789	
	0.0	2837	2865	2810	2740	2754	2803	
	7.5	2878	2906		2713	2726	2811	ta di kata
16	5.0	2946	2948	2823	2713	2698	2827	802
	2.5	3001	2002	2851	2713	2570		
16	0.0	3070	3031	2851	2699	2628	2857	
15	7.5	3152	3086	2893	2685	2586	2883	
15	5.0	32/5	3169	2879	2643	2330	2302	1346
	2.5	3398	3266	2893	2616	2516	2933	
15	0.0	3577	3377	2920	2574	2460	2973	
14	7.5	3700	3529	2948	2547	2391	3017	
14	5.0	3700 3837 4015	3654	3017	2505	2335	3065	1927
	2.5	4015	3792	3100	2450	2265	3121	
14	0.0	4193	3889	3183	2408	2195	3169	
	7.5	4481	4083	3239	2353	2111	3243	
135	5.0	4947	4360	3239	2297	2013	3344	2623
13	2.5	5454	4747	3239	2270	1929	3487	
130	0.0	6084	5328	3252	2228	1817	3690	
. 12	7.5	6783	5924		2201	1734	3940	
12	5.0	7564	6657	3737	2201	1650	4300	3846
12	2.5	8153	7363	4207	2228	1580	4666	
120	0.0	8304	7681	4595	2242	1524	4858	
	7.5	8112	7571	4761	2228	1440	4834	
11:	5.0	7537	7100	4567	2256	1342	4591	4381
11	2.5	6646	6131	4138	2256	1230	4116	
11	0.0	5659	5218	3681	2173	1104	3614	
	7.5	5317	4955	3432	1965	965	5 6	
10	5.0	4837	4609	3059	1689	811	3045	2968
10	2.5		2934	2173	1204	643	2033	
	0.0	2275	2228	1605	886	433	1518	
	7.5	1425	1453	1066	595	322	997	
	5.0	713	747	540	318	210	517	696
	2.5	233	221	194	138	126	183	
9	0.0	Ø	Ø	Ø	Ø	<i>Q</i> 1	Ġ	

LIGHTING SCIENCES INC. 7730 E. REDFIELD ROAD, SCOTTSDALE INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. LSI 1069 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE
HIGH REFLECTANCE ALUM. REFLECTOR AND HIGH TRANSMITTANCE COVER GLASS
ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

COEFFICIENTS OF UTILIZATION

EFFECTIVE FLOOR CAVITY REFLECTANCE = .20

CC	70		30	1 7	20		70	3 0	ea	50	1.0	e 0	30	10	e a	10	1.0	Ø
WALI	. 70	שכ	30	7.0	710	20	30	TA	50	30	10	30	30	10	26	30	10	ю
RCR																		
1	.66	.63	.60	.58	.56	.54	.52	.49	. 37	.36	.35	. 22	.21	.20	.07	.07	.07	.00
2	.60	.55	.50	.47	.51	.47	.43	.40	.32	.30	.28	.19	.18	.17	.06	.06	.06	.00
3	.55	.48	.43	.39	.47	.41	.37	.34	. 29	.26	. 24	.17	.15	.14	.06	.05	.05	.00
4	.50	.42	.37	.33	.42	.36	.32	.28	. 25	.22	.20	.15	.13	.12	.05	.05	.04	.00
5	.46	.37	.32	.28	. 39	.32	.28	.24	.22	.19	.17	.13	.11	.10	.04	.04	.04	. ଡଟ
6	.42	.33	.28	.24	.36	.29	. 24	.21	.20	.17	.15	.12	.10	.09	.04	.03	.03	.00
7	.38	.30	. 24	.20	. 33	.26	.21	.18	.18	.15	.13	.10	.09	.08	.04	.03	.03	. ମ ମ
8	.35	. 27	.21	.18	.30	.23	.19	.15	.16	.13	.11	.10	.08	.07	.03	.03	.02	.00
9	.33	. 24	.19	.15	. 28	.21	.16	.13	.14	.12	.10	.09	.07	.06	.03	.02	.02	.00
10	.30	.22	.17	.14	. 26	.19	.15	.12	.13	.10	.08	.08	.06	.05	.03	.02	.02	.00

DETERMINED IN ACCORDANCE WITH CURRENT IES PUBLISHED PROCEDURES



LIGHTING SCIENCES INC.

7730 E. Redfield Rd. Scottsdale Arizona 85260 602-991-9260

CERTIFIED TEST REPORT NO. LSI 1072 COMPUTED BY LSI PROGRAM **TEST-LITE**

No coming

INDIRECT AMBIENT PROTOTYPE LUMINAIRE STIPPLED ALUMINUM REFLECTOR AND CLEAR COVER GLASS ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

18.250
3.250
150
ACROSS 45
ALONG
6000
120
THE
X2000/
90
TXX/XHHY

	CANDI	CEPOWE	R SUMM	λRY		OUTPUT LUMENS
ANGLE	ACROSS	67.5	4.5	22.5	ALONG	
180	2718	2718	2718	2718	2718	
175	2732	2760	2732	2704	2718	261
170	2828	2815	2746	2690	2677	
165	2952	2926	2801	2663	2621	792
160	3103	3023	2843	2521	2566	
155	3295	3176	2885	2580	2459	1335
150	3542	3356	2940	2524	2372	
145	3803	3550	2982	2455	2247	1893
140	4228	3814	3065	2372	2122	
135	4819	4161	3079	2233	1969	2515
130	5738	4798	3162	2080	1775	
125	6521	5575	3412	1969	1595	3317
120	6576	5811	3731	1803	1415	
115	5780	5020	3481	1595	1207	3284
110	4105	3647	2857	1387	957	
105	3446	3065	2274	1040	666	2053
100	1428	1290	1123	458	333	
95	467	444	402	194	139	439
90	Ø	0	Ø	Ø	Ø	

ZONAL LUMENS AND PERCENTAGES

ZONE	LUMENS	% LAMP	% FIXTURE
180-150	2387	9.55	15.02
180-140	4280	17.12	26.94
180-120	10112	40.45	63.65
180-90	15888	63.55	100.00
140-90	11607	46.43	73.06
120-90	5775	23.10	36.35
180-90	Ø	0.00	0.00
0-180	15888	63.55	100.00

** EFFICIENCY = 63.55% **

CERTIFIED BY:

Tan leus.

DATE: JUL 06, 1979

PREPARED FOR:

LIGHTING R & D

TESTED IN ACCORDANCE WITH IES PROCEDURES. TEST DISTANCE = 8 METERS (26 FT.)

LIGHTING SCIENCES INC. 7730 E. REDFIELD ROAD, SCOTTSDALE INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. LSI 1072 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE STIPPLED ALUMINUM REFLECTOR AND CLEAR COVER GLASS ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

CANDLEPOWER DATA IN 2.5 DEGREE STEPS

ACROSS 67.5 45 22.5 ALONG AVERAGE LUMENS 180.0 2718 2718 2718 2718 2718 2718 2718 2718	ANGLE			Đĩ	A NI E			OUTPUT
180.0 2718 2718 2718 2718 2718 2718 2718 2718 2718 2718 2718 2704 2720 175.0 2732 2760 2732 2704 2718 2730 261 172.5 2759 2760 2732 2704 2690 2730 261 170.0 2828 2815 2746 2690 2677 2751 166.5 2869 2899 2774 2690 2649 2780 165.0 2952 2926 2801 2663 2621 2794 792 162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2566 2830 157.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 150.0 3542	ANGLE	ACROSS	67.5			ALONG	AVERAGE	
177.5 2718 2718 2732 2718 2704 2720 2720 2732 2760 2732 2704 2718 2730 261 172.5 2759 2760 2732 2704 2690 2730 170.0 2828 2815 2746 2690 2677 2751 167.5 2869 2899 2774 2690 2649 2780 2794 792 165.0 2952 2926 2801 2663 2621 2794 792 162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2566 2830 155.0 3295 3176 2885 2580 2469 2880 1335 155.0 3295 3176 2885 2580 2469 2880 1335 155.0 3542 3356 2940 2524 2372 2912 1560.0 3542 3355 2982 2455 2247 3003 1893								
175.0 2732 2760 2732 2704 2718 2730 261 172.5 2759 2760 2732 2704 2690 2730 2730 170.0 2828 2815 2746 2690 2677 2751 2675 167.5 2869 2899 2774 2690 2649 2780 792 165.0 2952 2926 2801 2663 2621 2794 792 162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2566 2830 2858 155.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 2150 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247	180.0	2718	2718	2718	2718	2718	2718	
172.5 2759 2760 2732 2704 2690 2730 170.0 2828 2815 2746 2690 2677 2751 167.5 2869 2899 2774 2690 2649 2780 165.0 2952 2926 2801 2663 2621 2794 792 162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2566 2830 157.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 2550 356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 147.5 3638 3550 2982 2455 2247 2912 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 <td>177.5</td> <td>2718</td> <td>2718</td> <td></td> <td>2718</td> <td></td> <td>2720</td> <td></td>	177.5	2718	2718		2718		2720	
170.0	175.0	2732	2760	2732	2704	2718	2730	261
167.5 2869 2899 2774 2690 2649 2780 165.0 2952 2926 2801 2663 2621 2794 792 162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2566 2830 157.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489	172.5	2759	2760	2732	2704	2690	2730	
165.0 2952 2926 2801 2663 2621 2794 792 162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2830 157.5 3199 3107 2871 25924 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>								
162.5 3034 2968 2829 2635 2607 2813 160.0 3103 3023 2843 2621 2566 2830 157.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258		2869	2899	2774	2690	2649	2780	
160.0 3103 3023 2843 2621 2566 2830 157.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 1375 4489 3966 3051 2302 2053 3148 135.0 44819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080	165.0	2952	2926	2801	2663	2621	2794	792
157.5 3199 3107 2871 2593 2524 2858 155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219	162.5	3034	2968	2829	2635	2607	2813	
155.0 3295 3176 2885 2580 2469 2880 1335 152.5 3391 3273 2912 2552 2427 2912 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0	160.0	3103	3023	2843	2621	2566	2830	
152.5 3391 3273 2912 2552 2427 2912 150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835	157.5	3199	3107	2871	2593	2524	2858	
150.0 3542 3356 2940 2524 2372 2944 147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576	155.0	3295	3176	2885	2580	2469	2880	1335
147.5 3638 3453 2968 2496 2316 2974 145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246	152.5	3391	3273	2912	2552	2427	2912	
145.0 3803 3550 2982 2455 2247 3003 1893 142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780	150.0	3542	3356	2940	2524	2372	2944	
142.5 4022 3647 3037 2399 2191 3048 140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 110.0 4105	147.5	3638	3453	2968	2496	2316	2974	
140.0 4228 3814 3065 2372 2122 3106 137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105	145.0	3803	3550	2982	2455	2247	3003	1893
137.5 4489 3966 3051 2302 2053 3148 135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762	142.5	4022	3647	3037	2399	2191	3048	
135.0 4819 4161 3079 2233 1969 3217 2515 132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 2606 2606 2606 2606 2606 2606 2606 2606 2606 2606 2606 2606	140.0	4228	3814	3065	2372	2122	3106	
132.5 5258 4438 3079 2163 1858 3310 130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 105.0 3446 <	137.5	4489	3966	3051	2302	2053	3148	
130.0 5738 4798 3162 2080 1775 3449 127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 <td< td=""><td>135.0</td><td>4819</td><td>4161</td><td>3079</td><td>2233</td><td>1969</td><td>3217</td><td>2515</td></td<>	135.0	4819	4161	3079	2233	1969	3217	2515
127.5 6219 5187 3245 2025 1678 3601 125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 3333 222 633 95.0 467 444 402 194 139 336 439	132.5	5258	4438	3079	2163	1858	3310	
125.0 6521 5575 3412 1969 1595 3753 3317 122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	130.0	5738	4798	3162	2080	1775	3449	* *
122.5 6658 5839 3592 1900 1512 3854 120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	127.5	6219	5187	3245	2025	1678	3601	
120.0 6576 5811 3731 1803 1415 3835 117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	125.0	6521	5575	3412	1969	1595	3753	3317
117.5 6246 5589 3717 1692 1318 3695 115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	122.5	6658	5839	3592	1900	1512	3854	
115.0 5780 5020 3481 1595 1207 3397 3284 112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	120.0	6576	5811	3731	1803	1415	3835	
112.5 5011 4271 3176 1512 1082 3001 110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	117.5	6246	5589	3717	1692	1318	3695	
110.0 4105 3647 2857 1387 957 2606 107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	115.0	5780	5020	3481	1595	1207	3397	3284
107.5 3762 3356 2593 1220 818 2365 105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	112.5	5011	4271		1512	1082	3001	
105.0 3446 3065 2274 1040 666 2109 2053 102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	110.0	4105	3647	2857	1387	957	2606	
102.5 2128 1900 1595 735 499 1386 100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	107.5	3762	3356	2593	1220	818	2365	
100.0 1428 1290 1123 458 333 938 97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	105.0	3446	3065	2274	1040	666	2109	2053
97.5 906 874 763 333 222 633 95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	102.5	2128	1900	1595	735	499	1386	
95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	100.0	1428	1290	1123	458	333	938	
95.0 467 444 402 194 139 336 439 92.5 165 153 160 111 69 135	97.5	906	874	763	333	222	633	
	95.0	467	444	402				439
	92.5	165	153	160	111	69	135	
	90.0	Ø	Ø	Ø	Ø	Ø	Ø	

LIGHTING SCIENCES INC. 7730 E.ØREDFIELD ROAD, SCOTTSDALE INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO.0LSI 1072 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE STIPPLED ALUMINUM REFLECTOR AND CLEAR COVER GLASS ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

COEFFICIENTS OF UTILIZATION

EFFECTIVE FLOOR CAVITY REFLECTANCE = .20

CC		8	Ø			7	Ø			5Ø			30			10		Ø
WAL:	L 70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	P
RCR																		
1	.56	.53	.51	.49	.48	.46	.44	.41	.31	.30	.29	.18	.18	.17	.06	.06	,06	.00
2	.51	.46	.43	.39	.43	.40	.37	. 34	.27	. 25	.24	.16	.15	.14	.05	.05	.05	. ព ព
3	.46	.41	.36	.33	.39	.35	.31	. 29	. 24	.22	.20	.14	.13	.12	.05	.04	.04	.00
4	.42	.36	.31	.28	.36	.31	. 27	. 24	.21	.19	.17	.12	.11	.10	.04	.04	.04	.00
5	.38	.31	.27	.23	.33	. 27	.23	.20	.19	.16	.14	.11	.10	.09	.04	.03	.03	.00
6	.35	. 28	.23	.20	.30	.24	.20	.17	.17	.14	.12	.10	.08	.07	.03	.03	.03	.00
7	.32	. 25	.20	.17	.28	. 2,2	.18	.15	.15	.12	.11	.09	.07	.06	.03	.03	.02	.00
8	.30	.23	.18	.15	.25	.19	.16	.13	.14	.11	.09	.08	.07	.06	.03	.02	.02	.00
9	.28	. 20	.16	.13	. 24	.18	.14	.11	.12	.10	.08	.07	.06	.05	.02	.02	.02	.00
10	. 26	.19	.14	.11	.22	.16	.12	.10	.11	.09	.07	.07	.05	.04	.02	.02	.01	.00

There can be a fell of the manner of the first

DETERMINED IN ACCORDANCE WITH CURRENT IES PUBLISHED PROCEDURES

16 = police to per

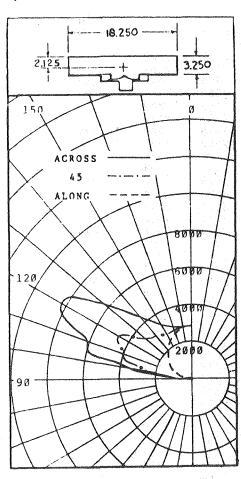


LIGHTING SCIENCES INC.

7730 E. Redfield Rd. Scottsdale Arizona 85260 602-991-9260

CERTIFIED TEST REPORT NO. LSI 1075 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE HIGH REFLECTANCE ALUMINUM REFLECTOR WITH NO COVER GLASS ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.



	CANDI	LEPOWE	R SUMM	ARY		OUTPUT LUMENS
ANGLE	ACROSS	67.5	45	22.5	ALONG	
180	2807	2807	2807	2807	2807	
175	2835	2807	2807	2821	2793	268
170	2890	2834	2793	2779	2751	
165	2932	2876	2793	2737	2710	794
150	2960	2903	2779	2682	2626	
155	3140	2972	2766	2612	2529	1299
150	3446	3151	2766	2529	2418	
145	3793	3398	2848	2418	2279	1848
140	4307	3784	2999	2307	2112	
135	5197	4348	3123	2182	1931	2592
130	6294	5393	3288	2112	1751	
125	7656	6604	3949	2154	1570	3850
120	8309	7430	4733	2168	1431	
115	7698	6838	4540	2223	1264	4387
110	6155	5407	4059	2251	1098	
105	6030	5476	3825	2015	931	3584
100	3488	3261	2614	1348	611	
95	1556	1747	1280	723	389	1309
90	Ø	Ø	Ø	Ø	0)	

. ZONAL LUMENS AND PERCENTAGES

ZONE	LUMENS	& LAMP	% FIXTURE
180-150	2361	9.45	11.85
180-140	4209	16.84	21.12
180-120	10651	42.60	53.44
180-90	19931	79.73	100.00
140-90	15721	62.89	78.88
120-90	9280	37.12	46.56
180-90	Ø	0.00	0.00
0-180	19931	79.73	100.00

** EFFICIENCY = 79.73% **

CERTIFIED BY:

DATE: JUL 12, 1979

PREPARED FOR:

LIGHTING R & D SAN RAFAEL, CA

TESTED IN ACCORDANCE WITH IES PROCEDURES. TEST DISTANCE = 8 METERS (26 FT.)

LIGHTING SCIENCES INC. 7730 E. REDFIELD ROAD, SCOTTSDALE INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. LSI 1075 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE
HIGH REFLECTANCE ALUMINUM REFLECTOR WITH NO COVER GLASS
ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

CANDLEPOWER DATA IN 2.5 DEGREE STEPS

ANGLE			PL	ANE			OUTPUT
	ACROSS	67.5	45	22.5	ALONG	AVERAGE	LUMENS
180.0	2807	2807	2807	2807	2807	2807	
177.5	2821	2807	2807	2807	2807	2809	
175.0	2835	2807	2807	2821	2793	2812	268
172.5	2876	2821	2807	2793	2793	2814	
170.0	2890	2834	2793	2779	2751	2807	
167.5	2918	2848	2807	2765	2723	2810	
165.0	2932	2876	2793	2737	2710	2807	794
162.5	2946	2876	2793	2710	2682	2798	
160.0	2960	2903	2779	2682	2626	2789	
157.5	3029	2903	2766	2668	2571	2784	
155.0	3140	2972	2766	2612	2529	2796	1299
152.5	3251	3054	2752	2571	2473	2810	
150.0	3446	3151	2766	2529	2418	2844	
147.5	3613	3275	2793	2473	2348	2880	
145.0	3793	3398	2848	2418	2279	2925	1848
142.5	4030	3632	2917	2362	2195	3006	
140.0	4307	3784	2999	2307	2112	3075	
137.5	4655	4018	3068	2237	2029	3166	
135.0	5197	4348	3123	2182	1931	3304	2592
132.5	5753	4829	3192	2140	1834	3489	
130.0	6294	5393	3288	2112	1751	3704	
127.5	6989	5930	355Ø	2112	1640	3977	
125.0	7656	6604	3949	2154	1570	4330	3850
122.5	8156	7182	4417	2154	1501	4645	
120.0	8309	7430	4733	2168	1431	4800	
117.5	8170	7320	4761	2126	1348	4741	
115.0	7698	6838	4540	2223	1264	4521	4387
112.5	6892	5985	4265	2279	1181	4141	
110.0	6155	5407	4059	2251	1098	3836	
107.5	6142	5448	4045	2126	1014	3799	
105.0	6030	5476	3825	2015	931	3699	3584
102.5	4085	3687	2944	1501	792	2643	
100.0	3488	3261	2614	1348	611	2318	
97.5	2640	2669	2078	1098	528	1857	
95.0	1556	1747	1280	723	389	1181	1309
92.5	584	688	537	375	236	502	
90.0	Ø	Ø	Ø	Ø	Ø	Ø	

LIGHTING SCIENCES INC. 7730 E. REDFIELD ROAD, SCOTTSDALE INDUSTRIAL AIRPARK SCOTTSDALE, ARIZONA 85260.

CERTIFIED TEST REPORT NO. LSI 1075 COMPUTED BY LSI PROGRAM **TEST-LITE**

INDIRECT AMBIENT PROTOTYPE LUMINAIRE
HIGH REFLECTANCE ALUMINUM REFLECTOR WITH NO COVER GLASS
ONE C250DX4 HPS LAMP. LUMEN RATING = 25,000 LMS.

COEFFICIENTS OF UTILIZATION

EFFECTIVE FLOOR CAVITY REFLECTANCE = .20

CC			3 Ø				7 Ø			50			30			10		Ø
WAL	70	50	30	10	70	50	30	10	50	30	10	50		10	50	30	10	Ø
RCR																		
1	.70	.67	.64	.61	.60	. 57	.55	.52	.39	. 38	.37	.23	.22	.21	.08	.07	.07	. Ø ß
2	.53	.58	.53	.49	.54	.50	.46	.43	. 34	.32	.30	.20	.19	.18	.07	.06	.06	.00
3	.58	.51	.46	.41	.49	. 44	.39	.36	.30	. 27	.25	.18	.16	.15	.06	.05	.05	.00
4	.53	.45	.39	.35	.45	. 39	.34	.30	. 27	. 24	.21	.16	.14	.13	.05	.05	.04	.00
5	.48	.39	.34	. 29	.43	. 34	.29	. 25	. 24	. 20	.18	.14	.12	.11	.05	.04	.04	.00
6	.44	. 35	. 29	. 25	.38	.30	.25	. 22	.21	.18	.16	.12	.11	.09	.04	.04	. ЙЗ	.00
7	.41	.32	.26	.21	.35	. 27	.22	.19	.19	.16	.13	.11	.09	.08	.04	.03	.03	.00
8	.37	.28	.23	.19	.32	. 24	.20	.16	.17	.14	.12	.10	.08	.07	.03	.03	.02	. 00
9	.35	.26	.20	.15	. 29	. 22	.17	.14	.15	.12	.10	.09	.07	.06	.03	. n 2	.02	. 00
10	.32	.23	.18	.14	. 27	. 20	.16	.12	.14	.11	.09	.08	.07	.05	.03	.02	,02	. 00

DETERMINED IN ACCORDANCE WITH CURRENT IES PUBLISHED PROCEDURES

in the first particular to the first section of the